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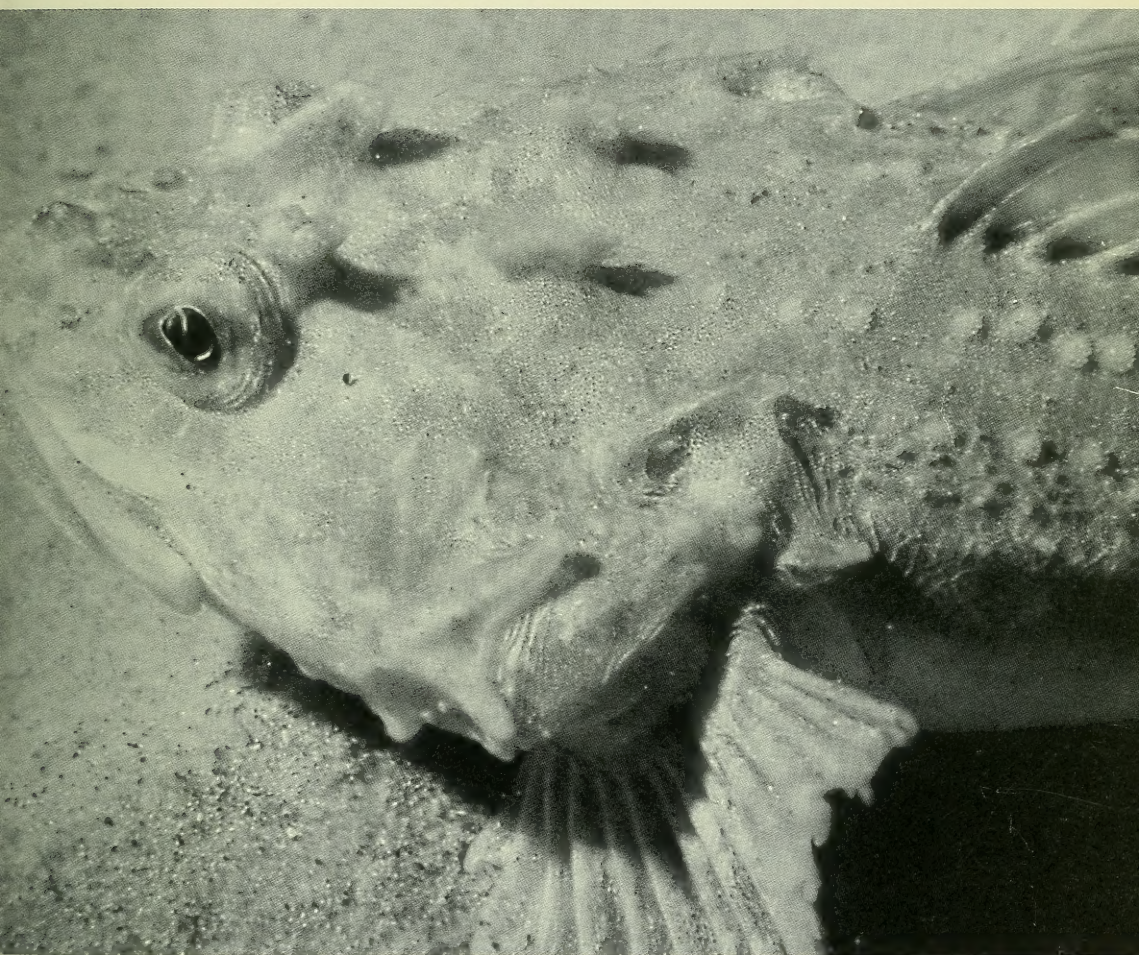

Volume 104, Number 1 January-March 1990

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The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

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Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; (613) 996-1755; **Assistant to Editor:** P. J. Narraway; **Copy Editor:** Louis L'Arrivée

Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665

Book Review Editor: Dr. J. Wilson Eedy, R. R. 1, Moffat, Ontario L0P 1J0

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Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club*, 1879-1886, and *The Ottawa Naturalist*, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist — Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: The Fourhorn Sculpin, *Myoxocephalus quadricornis*, Lady Franklin Point, Northwest Territories, July 1979. Photograph by R. K. Kashino of Vancouver, courtesy of D. E. McAllister, Canadian Museum of Nature, Ottawa. See status report by J. Houston, pages 7–13.

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THE CANADIAN FIELD-NATURALIST

Volume 104

1990

THE OTTAWA FIELD-NATURALISTS' CLUB

OTTAWA CANADA

The Canadian Field-Naturalist

Volume 104, Number 1 January-March 1990

Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: VI

R. R. CAMPBELL

Department of Fisheries and Oceans, 200 Kent Street, Ottawa, Ontario K1A 0E6

Campbell, R. R. *Editor.* 1990. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: VI. Canadian Field-Naturalist 104(1): 1-6.

Twenty-one status reports representing those species of fish and marine mammals which were assigned status at the 1989 COSEWIC General Meeting have been prepared for publication. Committee and Subcommittee (Fish and Marine Mammals) activities are briefly discussed, including changes to category definitions introduced in 1988. Also of interest, is the creation of the RENEW Committee which will attempt to carry the process to the next logical step — recovery plans and implementation, for endangered species. Current lists of status assignment for fish and marine mammals and for species yet to be considered, or which are under consideration, are presented in tabular form.

Vingt-et-un rapports de statut représentant tout les données de statut aux poissons et aux mammifères marins donnés un statut à la réunion de CSEMDC ont été préparés pour publication. Les activités du Comité et du sous-comité (poissons et mammifères marins) sont brièvement discutées incluyant des changements aux définitions de catégorie, introduitent en 1988. On présente aussi des renseignements concernant le Comité "RENEW" qui essayera de porter le processus à la prochaine étape logique — planification et implementation des planifications pour les espèces en danger de disparition. Listes currents des espèces aux poissons et aux mammifères marins déjà nominées et des espèces lesquelles on a encore besoin de considerer ont montré en forme tabulaire.

Key Words: Rare and endangered species, fish, marine mammals, COSEWIC, status, Canada.

As indicated in previous submissions (Campbell 1984, 1985, 1987, 1988 and 1989), the intent of the Subcommittee on Fish and Marine Mammals is to publish the status reports (on those species of fish and marine mammals) which the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) have reviewed, approved and used as a basis for the assignment of status to species in jeopardy in Canada. The group of 21 reports presented herein represent the fish and marine mammal component of those species assigned status in 1989. It is hoped that we will have the continuing support of the Department of Fisheries and Oceans to offer, in succeeding volumes, those reports reviewed in future years (Table 1 presents those species assigned status to April 1989).

Progress

COSEWIC has undertaken to make available to all Canadians, supporting information on each species classified (see Cook and Muir 1984). The Fish and Marine Mammal Subcommittee has been able to use this journal as one step in achieving the goal. A series of reports were published in 1984, 1985, 1987, 1988, and 1989 [see *Canadian Field-Naturalist* 98(1): 63-133; 99(3): 404-450; 102(2): 165-309; 103(2): 147-239] and the encouraging response to these publications has enabled us to continue.

Contributions to the Committee of $10 000 made by the Department of Fisheries and Oceans and Environment Canada in 1988 were once again matched by World Wildlife Fund Canada, permitting the contracting of several new reports in 1988. The Fish and Marine Mammal Subcommittee was able to take advantage of this and 25 reports were initiated in 1988-1989. Although there are still a number of reports in preparation or under review (Table 2), the number of species still awaiting consideration has been reduced to 25 (Table 3). It is the Subcommittee's goal to clear this list by 1992.

There are currently 28 status reports on fish species, and 26 on marine mammal species under

TABLE 1. Fish and marine mammal species with assigned COSEWIC status to April 1989.

Species	Scientific Name	Status	Date Assigned
FISH			
Lake Sturgeon	*Acipenser fulvescens*	NIAC	April 1986
Bloater	*Coregonus hoyi*	NIAC	April 1988
Blueback Herring	*Alosa aestivalis*	NIAC	April 1980
Hornyhead Chub	*Nocomis biguttatus*	NIAC	April 1988
River Chub	*Nocomis micropogon*	NIAC	April 1988
Redfin Shiner	*Notropis umbratilis*	NIAC	April 1988
Golden Redhorse	*Moxostoma erythrurum*	RANSDR[a]	April 1989
Least Darter	*Etheostoma microperca*	RANSDR	April 1989
River Darter	*Percina shumardi*	RANSDR	April 1989
Green Sunfish	*Lepomis cyanellus*	NIAC	April 1987
Longear Sunfish	*Lepomis megalotis*	NIAC	April 1987
Spoonhead Sculpin	*Cottus ricei*	RANSDR	April 1989
Brook Silverside	*Labidesthes sicculus*	RANSDR	April 1989
Lake Lamprey*	*Lampetra macrostoma*	Rare	April 1986
Green Sturgeon	*Acipenser medirostris*	Rare	April 1987
Shortnose Sturgeon	*Acipenser brevirostrum*	Rare	April 1980
Spotted Gar	*Lepisosteus oculatus*	Rare	April 1983
Kiyi	*Coregonus kiyi*	Rare	April 1987
Squanga Whitefish*	*Coregonus* sp.	Rare	April 1988
Pacific Sardine	*Sardinops sagax*	Rare	April 1987
Silver Chub	*Hybopsis storeriana*	Rare	April 1985
Umatilla Dace	*Rhinichthys umatilla*	Rare	April 1988
Bigmouth Shiner	*Notropis dorsalis*	Rare	April 1985
Pugnose Shiner	*Notropis anogenus*	Rare	April 1985
Silver Shiner	*Notropis photogenis*	Rare	April 1983**
Pugnose Minnow	*Notropis emiliae*	Rare	April 1985
Redside Dace	*Clinostomus elongatus*	Rare	April 1987
Speckled Dace	*Rhinichthys osculus*	Rare	April 1980+
Central Stoneroller	*Campostoma anomalum*	Rare	April 1985
Banded Killifish (Newfoundland)	*Fundulus diaphanus*	Vulnerable[b]	April 1989
Blackstripe Topminnow	*Fundulus notatus*	Rare	April 1985
Bigmouth Buffalo	*Ictiobus cyprinellus*	Vulnerable	April 1989
Black Buffalo	*Ictiobus niger*	Vulnerable	April 1989
Spotted Sucker	*Minytrema melanops*	Rare	April 1983
River Redhorse	*Moxostoma carinatum*	Rare	April 1983**
Brindled Madtom	*Notorus miurus*	Rare	April 1985
Orangespotted Sunfish	*Lepomis humilis*	Vulnerable	April 1989
Redbreast Sunfish	*Lepomis auritus*	Vulnerable	April 1989
Fourhorn Sculpin (Arctic Islands)	*Myoxocephalus quadricornis*	Vulnerable	April 1989
Giant Stickleback*	*Gasterosteus* sp.	Rare	April 1980
Unarmoured Stickleback*	*Gasterosteus* sp.	Rare	April 1983
Blackline Prickleback	*Acantholumpenus mackayi*	Vulnerable	April 1989
Bering Wolffish	*Anarichus orientalis*	Vulnerable	April 1989
Lake Simcoe Whitefish*	*Coregonus clupeaformis* spp.	Threatened	April 1987
Blackfin Cisco	*Coregonus nigripinnis*	Threatened	April 1988
Shortnose Cisco	*Coregonus reighardi*	Threatened	April 1987
Shortjaw Cisco	*Coregonus zenithicus*	Threatened	April 1987
Deepwater Sculpin (Great Lakes Watershed)	*Myoxocephalus thompsoni*	Threatened	April 1987
Black Redhorse	*Moxostoma duquesnei*	Threatened	April 1988
Copper Redhorse*	*Moxostoma hubbsi*	Threatened	April 1987
Margined Madtom	*Noturus insignis*	Threatened	April 1989
Enos Lake Stickleback*	*Gasterosteus* sp.	Threatened	April 1988
Shorthead Sculpin	*Cottus confusus*	Threatened	November 1983
Aurora Trout	*Salvelinus fontinalis timagamiensis*	Endangered	April 1987*
Acadian Whitefish*	*Coregonus canadensis*	Endangered	April 1983
Salish Sucker	*Catostmus* sp.	Endangered	April 1986
Gravel Chub	*Hybopsis x-punctata*	Extirpated	April 1987***
Paddlefish	*Polyodon spathula*	Extirpated	April 1987
Deepwater Cisco	*Coregonus johannae*	Extinct	April 1988

TABLE 1. Fish and marine mammal species with assigned COSEWIC status to April 1989 (*concluded*).

Species	Scientific Name	Status	Date Assigned
FISH (continued)			
Lonjaw Cisco	*Coregonus alepnae*	Extinct	April 1988
Banff Longnose Dace*	*Rhinichthys cataractae smithi*	Extinct	April 1987
Blue Walleye	*Stirzostedion vitreum glaucum*	Extinct	April 1985
MARINE MOLLUSCS			
Northern Abalone	*Haliotis kamtschatkana*	N/A	April 1988
MARINE MAMMALS			
California Sea Lion	*Zalophus californianus*	NIAC	April 1987
Stellar Sea Lion	*Eumetopias jubatus*	NIAC	April 1987
Atlantic Walrus	*Odobenus rosmarus rosmarus*		
Eastern Arctic		NIAC	April 1987
Northwest Atlantic		Extirpated	April 1987
Grey Whale	*Eschrichtius robustus*		
Northeast Pacific		NIAC	April 1987
Northwest Atlantic		Extirpated	April 1987
Hooded Seal	*Cystophora cristata*	NIAC	April 1986
Northern Elephant Seal	*Mirounga angustirostris*	NIAC	April 1986
Ringed Seal	*Phoca hispida*	RANSDR	April 1989
Dall's Porpoise	*Phocoenoides dalli*	RANSDR	April 1989
Narwhal	*Monodon monoceros*	NIAC	April 1986**
Blainville's Beaked Whale	*Mesoplodon densirostris*	RANSDR	April 1989
Hubb's Beaked Whale	*Mesoplodon carlhubbsi*	RANSDR	April 1989
Stejneger's Beaked Whale	*Mesoplodon stejnegeri*	RANSDR	April 1989
True's Beaked Whale	*Mesoplodon mirus*	RANSDR	April 1989
Beluga	*Delphinapterus leucas*		
Beaufort Sea		NIAC	April 1986
St. Lawrence River		Endangered	April 1983
Eastern Hudson Bay		Threatened[i]	April 1988
Unagava Bay		Endangered[i]	April 1988
Sowerby's Beaked Whale	*Mesoplodon bidens*	Vulnerable	April 1989
Blue Whale	*Balaenoptera musculus*	Rare	April 1983
Fin Whale	*Balaenoptera physalus*	Rare	April 1987[+]
Sea Otter	*Enhydra lutris*	Endangered	May 1978°
Humpback Whale	*Megaptera novaeangliae*		
Northeast Pacific		Threatened	April 1982[-]
Northwest Atlantic		Rare	April 1985
Bowhead Whale	*Balaena mysticetus*	Endangered	April 1980°
Right Whale	*Eubalaena glacialis*	Endangered	April 1980/85[x]
Sea Mink	*Mustela macrodon*	Extinct	April 1985

NIAC — Not in Any COSEWIC Category (i.e., not in jeopardy)
N/A — Status not assigned. COSEWIC has no mandate for invertebrates. Report accepted and recommended NIAC Status agreed to, but not assigned.
[a]RANSDR — Use of NIAC dropped in 1988 — RANSDR is not a category = report accepted no status designation required.
*Endemic to Canada
[b]Vulnerable — 'Rare' category changed to 'Vulnerable' in 1988. Previous rare designations to be re-examined prior to automatic change to vulnerable.
†Updated April 1984 — no status change.
[-]Updated April 1985 — North Atlantic stock downlisted to "Rare".
[i]To be reviewed in 1990.
[x]Updated April 1985 — no status change.
[o]Updated April 1986 — no status change.
**Updated April 1987 — no status change.
***Updated April 1987 — previous status of 'Endangered' assigned April 1985.

review or in preparation (Table 2); several will be assigned status in 1990. In addition to soliciting further status reports on species of concern, the Subcommittee continues to obtain updates on the status of selected species as new information becomes available.

TABLE 2. Fish and marine mammal species for which status reports are in preparation, or under review August 1989.

Species	Scientific Name	Proposed Status
FISH		
Chestnut Lamprey	*Ichthyomyzon castaneus*	Vulerable
Darktail Lamprey	*Lethenteron alaskense*	Vulnerable
Northern Brook Lamprey	*Ichthyomyzon fossor*	Vulnerable
Atlantic Sturgeon	*Acipenser oxyrhynchus*	?
Lake Sturgeon†	*Acipenser fulvescens*	?
White Sturgeon	*Acipenser transmontanus*	?
Atlantic Salmon	*Salmo salar*	?
Bull Trout	*Salvelinus confluentus*	Vulnerable
Bering Cisco	*Coregonus laurettae*	?
Spring Cisco*	*Coregonus* sp.	?
Opeongo Whitefish*	*Coregonus* sp.	Threatened
Pygmy Whitefish	*Prosopium coulteri*	?
Pygmy Smelt	*Osmerus spectrum*	Vulnerable
Grass Pickerel	*Esox americanus vermiculatus*	Vulnerable
Cutlips Minnow	*Exoglossum maxillingua*	Vulnerable
Eastern Silvery Minnow	*Hybognathus nuchalis regius*	Vulnerable
Ghost Shiner	*Notropis buchanani*	Vulnerable
Lake Chubsucker	*Erimyzon sucetta*	Vulnerable
Jasper Longnose Sucker*	*Castostomus castostomus lacustris*	Vulnerable
Mountain Sucker	*Castostomus platyrhynchus*	Vulnerable
Leopard Dace	*Rhinichthys falcatus*	?
Greenside Darter	*Etheostoma blennioides*	Vulnerable
Warmouth	*Lepomis gulosus*	Vulnerable
Striped Bass	*Morone saxatilis*	Endangered
Eastern Sand Darter	*Ammocrypta pellucida*	Vulnerable
Y-Prickleback	*Allolumpenus hypochromus*	Vulnerable
Pixy Poacher*	*Occella impi*	Vulnerable
Bluefin Tuna	*Thunnus thynnus*	?
MARINE MAMMALS		
White-beaked Dolphin	*Lagenorhynchus albirostris*	?
Harbour Porpoise	*Phocoena phocoena*	?
Baird's Beaked Whale	*Berardius bairdii*	?
Cuvier's Beaked Whale	*Ziphius cavirostris*	Vulnerable
Beluga Whale	*Delphinapterus leucas*	
Cumberland Sound		Threatened
Western Hudson Bay		?
Ungava Bay°		Endangered
Eastern Hudson Bay/James Bay°		Threatened
Northern Bottlenose Whale	*Hyperoodon ampullata*	?
Bowhead Whale°	*Balaena mysticetus*	Endangered
Killer Whale	*Orcinus orca*	?
Long-finned Pilot Whale	*Globicephela malaena*	?
Right Whale°	*Eubalaena glacialis*	Endangered
False Killer Whale	*Pseudorca crassidens*	?
Risso's Dolphin	*Grampus griseus*	?
Sperm Whale	*Physeter catadon*	?
Pacific White-sided Dolphin	*Lagenorhynchus obliquidens*	?
Northern Right Whale Dolphin	*Lissodelphis borealis*	?
Striped Dolphin	*Stenella coeruleoalba*	?
Bottlenose Dolphin	*Tursiops truncatus*	?
Short-finned Pilot Whale	*Globicephala macrorhynchus*	Vulnerable
Pygmy Sperm Whale	*Kogia breviceps*	Vulnerable
Dwarf Sperm Whale	*Kogia simus*	Vulnerable
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	?
Common Dolphin	*Delphinus delphis*	?

*Endemic to Canada.
°Updated Status Report.

TABLE 3. Fish and Marine Mammal Species of Interest to COSEWIC — August 1989 (Not listed by priority)

Species	Scientific Name	Possible Status
FISH		
Red (Arctic) Char[1]	*Salvelinus alpinus* spp.	? (Landlocked populations — Quebec, New Brunswick, Newfoundland/Labrador)
Lake Herring	*Coregonus artedi*	Endangered in Lakes Erie and Ontario but widespread elsewhere.
Lake Whitefish	*Coregonus clupeaformis*	Threatened in Lakes Erie and Ontario but widespread elsewhere.
Mira Whitefish	*Coregonus* sp	Vulnerable
Round Whitefish	*Prosopium cylindraceum*	Vulnerable (Lakes Huron and Ontario but widespread elsewhere).
Pygmy Longfin Smelt*	*Spirinichus thaleichthys*	Vulnerable (landlocked population in Harrington Lake, British Columbia)
Chain Pickerel	*Esox niger*	Vulnerable (Quebec, New Brunswick, Nova Scotia)
Redfin Pickerel	*Esox americanus americanus*	Vulnerable (Quebec)
Chiselmouth	*Acrocheilus alutaceus*	Vulnerable (British Columbia)
Bluntnose Minnow	*Pimphales notatus*	Vulnerable (Manitoba)
Western Silvery Minnow	*Hybognathus argyritis*	? (Alberta)
Blackchin Shiner	*Notropis heterodon*	Vulnerable (Manitoba)
Rosyface Shiner	*Notropis rubellus*	Vulnerable (Manitoba)
Striped Shiner	*Notropis chrysocephalus*	Vulnerable (Ontario)
Weed Shiner	*Notropis texanus*	Vulnerable (Manitoba)
Nooky Dace	*Rhinichthys cataractae* spp.	Vulnerable (British Columbia)
Liard Hotspring Lake Chub*	*Couesius plumbeus* spp.	Vulnerable (British Columbia: Liard Hotspring)
Flathead Catfish	*Pylodictis olivaris*	? Ontario
Northern Madtom	*Noturus stigmosus*	Vulnerable (Ontario)
Texada Stickleback*	*Gasterosteus* sp.	Vulnerable
Tessellated Darter	*Ethestoma olmstedi*	Vulnerable (Ontario)
Channel Darter	*Percina copelandi*	Vulnerable (Ontario)
Cultus Pygmy Coastrange Sculpin*	*Cottus aleuticus*	Threatened (British Columbia)
Mottled Sculpin	*Cottus bairdi*	Vulnerable (British Columbia, Alberta)
Spinynose Sculpin	*Asemichthys taylori*	Vulnerable (British Columbia)

*Endemic to Canada.
[1]Not of immediate concern.

The 1989 General Meeting was also noteworthy in that changes in category definitions, introduced in 1988 (*see* Campbell 1988) were used for the first time in assignment of status. The use of "vulnerable" in status assignment commenced in 1989. Species assigned a "rare" status prior to, and including, August 1988 will remain as designated for now, but Subcommittee chairmen have been requested to provide recommendations for adoption of a change from "rare" to "vulnerable" on the basis of an updated report where necessary, and the status reaffirmed or redesignated as appropriate at the 1990 General Meeting. Species formerly declared to be "not in any category" and several listed as "threatened" may now require re-evaluation as well.

Due to confusion arising from the use of the designation of "not in any COSEWIC category" (NIAC), the use of this terminology has been discontinued. Commencing in 1989, species for which no status is assigned are simply annotated "report accepted, no status designation required". This will be accompanied by a brief explanatory note to indicate reasons, i.e., populations are stable and of no concern at this time, therefore, no status designation is required.

New Initiatives

A new national strategy for the prevention of extinction of wildlife species in Canada was launched in 1988. Although not a part of COSEWIC, this initiative arose through the impetus of COSEWIC and is intended to carry the

process to the next logical step. This strategy, acronym "RENEW" (for Recovery of Nationally Endangered Wildlife) will use COSEWIC status assignments and reports as the basis for selecting species for attention and recovery plans.

The concept is for all agencies, organizations, and individuals, interested and able to assist in the effort to preserve species, to agree to work together and follow the same process to achieve the same goal. The goal is to prevent species known to be at risk of extinction from becoming so, and to prevent other species from becoming at risk. The process will involve recovery programs for each species, based on comprehensive technical plans prepared by the best experts available. These will be approved by governments, and implemented in cooperation with other countries, individual interests, and other interested parties.

It is beyond the scope of this editorial to give a detailed explanation of the strategy. Interested parties may receive further detailed information by contacting the Office of Primary Interest, RENEW, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3.

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First and foremost, our thanks to the various authors who have so generously contributed their time and talent in support of COSEWIC and to the members of the Subcommittee for their unstinting efforts in reviewing the reports and their helpful comments.

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Accepted 10 October 1989

Status of the Fourhorn Sculpin, *Myoxocephalus quadricornis*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of the Fourhorn Sculpin, *Myoxocephalus quadricornis*, in Canada. Canadian Field-Naturalist 104(1): 7–13.

The Fourhorn Sculpin, *Myoxocephalus quadricornis*, is a widespread marine species, closely related to, and the probable progenitor of, the freshwater Deepwater Sculpin, *Myoxocephalus thompsoni*. The species is widely distributed and abundant in the Canadian Arctic and is an important forage species for other fish and for waterfowl. Marine populations are secure but evolving isolates in euryhaline lakes of the Canadian Arctic Archipelago are probably vulnerable as these lakes are sensitive to perturbations.

Le chabot à quatre cornes, *Myoxocephalus quadricornis*, est une espèce marine qui s'apparente étroitement au Chabot de profondeur, *Myoxocephalus thompsoni*, dont il est probablement l'ancêtre. Largement et abondamment répandu dans l'Arctique canadien, il constitue une source alimentaire importante pour la sauvagine et les autres espèces de poisson. Ce poisson marin pélagique est stable, mais les populations vivant dans les lacs euryhalins de l'Archipel arctique canadien sont probablement vulnérables étant donnée que ces eaux sont sensibles aux perturbations.

Key Words: Fourhorn Sculpin, *Myoxocephalus quadricornis*, chabot de quatre cornes, scorpion fish, cottidae, sculpins, rare and endangered fishes.

The Fourhorn Sculpin, *Myoxocephalus quadricornis* (Linnaeus 1738), originally described from the Baltic Sea, is a marine sculpin with a circumpolar Palearctic and Nearctic distribution (McAllister 1980). The species is closely related to the freshwater Deepwater Sculpin, *Myoxocephalus thompsoni* (Girard 1852). Their taxonomy has been the subject of several taxonomic and zoogeographic studies (Berg 1949; Walters 1955; McAllister 1961; Johnson 1964; McAllister and Aniskowicz 1976). McAllister and co-workers (McAllister 1961; McAllister and Aniskowicz 1976; McAllister et al. 1978) examined specimens of both forms and the various postglacial Arctic freshwater relicts which had been described (McAllister 1961; Hubbs and Lagler 1964; Johnson 1064; McPhail and Lindsey 1970; Dadswell 1972) and considered marine and freshwater forms as distinct species based on morphological characteristics, distribution and ecology. The postglacial Arctic relicts fell within the definitions of the marine Fourhorn Sculpin.

A status report has previously been completed on the freshwater form (Parker 1988). The present report deals solely with the "marine form" to which the name *Myoxocephalus quadricornis* is now restricted. The common and scientific names used here are those adopted by the American Fisheries Society (Robins et al. 1980).

Description

The Fourhorn Sculpin (Figure 1) is larger than the Deepwater Sculpin. It may attain a total length of up to 34.0 cm, but most specimens are somewhat smaller (McAllister 1980). The species can usually be easily distinguished from other cottids by the presence of four long protuberances (frontal and parietal spines) on the head (Scott and Scott 1988), which give rise to the name. There are also four well-developed preopercular spines as well as nasal and cleithral spines. The body is elongate with a slender caudal peduncle. The head is flattened and wide with close set eyes on the top of the head. There are two dorsal fins, the first being smaller and spiny; the caudal fin is square or truncate; the anal is soft rayed and has a long base; the pelvics are small, located well forward beneath the pectorals and have one spine and three to four soft rays; the pectorals are large and fanlike (*see* McAllister 1961; Scott and Scott 1988).

These fish lack typical scales and may have tubercles, sometimes reduced to prickles, above and below the lateral line which seldom extend past the insertion of the second dorsal fin (McAllister 1961). The second dorsal fin is usually larger in mature males than in the female and the pelvics are also notably larger. There may be tubercles on the second dorsal and pectoral fins which are not found on females (McAllister 1961; McPhail and Lindsey 1970).

The overall colouration is dark grey to brown, the back being darker, becoming lighter along the sides and light ventrally. The back and sides may be speckled or mottled and there are usually four to seven diffuse, saddle-like bands along the back and

*Vulnerable status approved and assigned by COSEWIC for those populations in landlocked lakes of the Arctic Archipelago 11 April 1989.

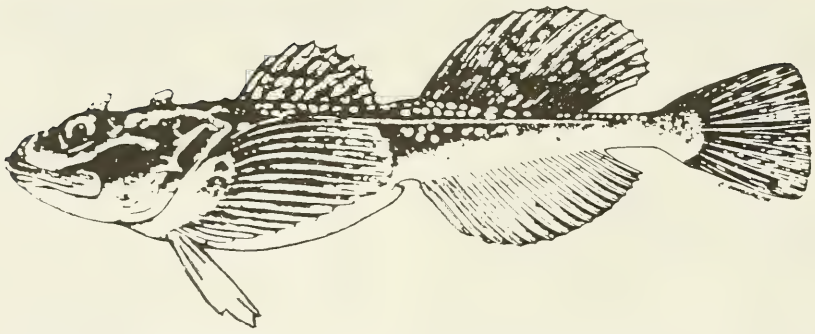

FIGURE 1. Drawing of the Fourhorn Sculpin, *Myoxocephalus quadricornis*, female from Peterson Bay, King William Island, Northwest Territories (231 mm standard length) [drawing by C. Douglas, courtesy of D. E. McAllister, Canadian Museum of Nature].

sides. The pectoral fins may have up to three diffuse darker bands, the pelvics may be spotted, and the dorsal and anal fins blotched. The caudal fin usually shows dark brown mottling. Males develop a rosy colouration under the head, on the lower pectoral fin, and on the anal and pelvic fins (McAllister 1961; Scott and Scott 1988).

Distribution

The Fourhorn Sculpin has a circumpolar marine distribution from the Barents to the Bering Seas in the Palearctic and from Alaska to Labrador in the Nearctic. Although present in eastern Greenland, the species is absent from Iceland, Norway and Spitzbergen (McPhail and Lindsey 1970; McAllister 1980). It occurs in both salt and brackish water, usually along the coast, but may be found up rivers as far as 150 km from the sea, and as landlocked relicts in some lakes (McAllister 1980).

In Canada, the species has been reported from many points along the arctic coast from Alaska through to Labrador (*see* Figure 2; National Museum of Natural Sciences (now Canadian Museum of Nature (NMC); Royal Ontario Museum (ROM): Ontario Ministry of Natural Resources (OMNR), records) including Hudson and James bays and most islands of the Arctic Archipelago (*see also* Leim and Scott 1961; McAllister 1961, 1980; McPhail and Lindsey 1970; McAllister and Aniskowicz 1976). The species has been recorded some 200 km up the Mackenzie River and in streams on Victoria, Baker and Cornwallis islands and north to northern Ellesmere Island (McPhail and Lindsey 1970). Johnson (1964) reported the presence of *Myoxocephalus quadricornis* in three lakes in Victoria Island and it has also been reported from lakes on Cornwallis Island and other islands in the archipelago (McAllister and Aniskowicz 1976).

Protection

No specific protective measures are in place in either Canada or the United States. General protection is provided in Canadian waters under the Fisheries Act.

Population Sizes and Trends

Information on the size and trends of Fourhorn Sculpin populations is limited mostly to presence-absence records. Most sampling has not been extensive or sequential, but at sites which have been visited in each of the last three decades (Figure 2, NMC; OMNR; ROM). The species appeared to be consistently common at most locations.

Craig and McCart (1976), in an overview of fish utilization of nearshore habitats for the Beaufort Sea coasts from the Colville River (Alaska) to the Mackenzie River (Northwest Territories), found the Fourhorn Sculpin to be widely distributed. For some areas they suggested that it often was the only fish to be found and very abundant. Lawrence et al. (1984) found the species to be abundant at 11 of 23 Tuktoyaktuk Peninsula locations where catches in 1978, 1979, and 1980, accounted for 2.8 to 37.2% of the fish taken depending on season and type of gear. Fyke nets provided better catches per unit effort than gill nets, seines or plankton nets. In early spring and midsummer collections, mature females were dominant and the total fish caught was less than in midsummer when juveniles were abundant (Lawrence et al. 1984). Lawrence et al. (1984) found no other species as abundant with the exception of the Arctic Flounder (*Liopsetta glacialis*). Fall collections provided the highest catches and the greatest number of sexually mature fish. The species appeared to avoid the Mackenzie plume and was scarce in collections in the inner Kugmallit Bay, although small numbers did move 1 km or so into coastal streams, but not beyond the area of tidal influence (Lawrence et al. 1984). Ratynski (1983) did find larval Fourhorn Sculpin in Tuktoyaktuk Harbour. None were recorded outside the harbour in Kugmallit Bay.

FIGURE 2. North American distribution of the Fourhorn Sculpin, *Myoxocephalus quadricornis* (from sources quoted in the text). ○ Alaska; ● Pre 1960 collection records; ▲ 1970's records; ■ Post 1970 records.

All in all, Fourhorn Sculpin are common in the Beaufort Sea (Ratynski 1983). Larvae and fish of all ages have been reported along the coasts of Alaska (Craig and McCart 1976; Craig et al. 1985), the Yukon coast (Kendel et al. 1975; Griffiths et al. 1975), and along the Tuktoyaktuk Peninsula (Jones and Den Beste 1977; Ratynski 1983; Lawrence et al. 1984). Fourhorn Sculpin are known to overwinter in bays and inlets along the coast (Lawrence et al. 1984).

Unfortunately, such detailed data are not available for the remainder of the Canadian Arctic coast, the eastern Arctic or the Arctic Archipelago. The Beaufort Sea has received considerable attention due to the Environmental Impact Assessment required by law in relation to hydrocarbon exploration and development in the area. The pace of activity has not been as great in the remainder of the Arctic and where sampling has been conducted, in Lancaster Sound and the Wellington Channel, the waters are deeper and the species not as likely to be found. Perhaps future activity in other areas of the Arctic will show the species to be as abundant there as in the west. Limited observations on or about Victoria, Cornwallis, Little Cornwallis and Ellesmere islands have indicated the presence of the species in these areas (McAllister 1961). Welch (1985) observed that Fourhorn Sculpins were not taken in freshwater and were not known from the Saqvaqjvac area of Northern Hudson Bay, but were common in the high Arctic in lakes that contain anadromous Arctic Char (*Salvelinus alpinis*).

Lake populations in the Arctic appear to be resident and to have been separated from their marine progenitors for several thousand years. While conspecific with the marine form, they do share distinctions and may be genetically differentiated. Their status should be evaluated

separately from the marine form (D.E. McAllister, personal communication).

Habitat

The Fourhorn Sculpin is a marine species, usually found in salt and brackish waters close to the coast in waters from 20 m to the intertidal zone (McAllister 1980). McAllister (1980) reported that the species may run up estuaries as far as 150 km from the sea but do not form resident populations in fresh water. Lawrence et al. (1984) indicated that the species avoided the Mackenzie Plume and that they did not seem to move more than 1 km into coastal streams or beyond the region of tidal influence.

Relict populations exist in some freshwater lakes or islands of the Arctic Archipelago, chiefly some lakes on Victoria, Cornwallis and Ellesmere islands (Johnson 1964; McAllister and Aniskowicz 1976) and perhaps others. Some of these lakes are meromictic, others are fresh, and McAllister and Aniskowicz (1976) considered that these were introduced by marine inundation following glaciation and isolated in freshening lakes during subsequent isostatic rebound. Occurrence of the species in these lakes is concurrent with that of the relict isopod *Mesidosethra entomon glacialis* which is not found in inland freshwaters on the mainland (McAllister and Aniskowicz 1976).

These authors suggested that these relict populations arose independently and more recently from the Fourhorn Sculpin than did the Deepwater Sculpin and should still be referred to as *Myoxocephalus quadricornis*; although morphologically different, the variations are not sufficiently significant to warrant subspecific rank (McAllister and Aniskowicz 1976). Variation between such relict populations would be greater than in the sea, as there would be little, if any, gene flow between lake populations, allowing genetic differences to accumulate in each, in contrast to marine populations which have potential for continuous gene flow. Differences in body lengths and mean meristic values suggest genetic differences exist. Lake temperatures and salinity in meromictic lakes fluctuates, especially during egg development and thus influences variability in characters such as the number of vertebrae (*see* McAllister and Aniskowicz 1976).

Adults of the species are benthic and the larvae are pelagic (Khan 1971; Khan and Faber 1973). During the open water season, juvenile and adult fish move into the nearshore brackish waters, seek preferred temperatures and salinity, and feed primarily on epibenthic invertebrates. Lawrence et al. (1984) reported that Fourhorn Sculpin caught from 1978 to 1980 along the Tuktoyaktuk Peninsula in June and July were at locations where temperatures ranged from 1 to 9°C and salinity was from 1 to 30. The largest catches occurred where salinity was above 10 and temperature less than 6.5°C. During August 1980, salinities ranged from 0.4 to 26.9 at capture sites and the largest numbers occurred where the salinity was 26.9 and the temperature 7.3°C (Lawrence et al. 1984). In the fall, these authors reported large catches at salinities of 3 to 27 and temperatures from 0.4 to 6.0°C. Craig et al. (1985) reported similar movements to coastal areas in the open water season.

The pelagic larvae have been reported to be common in the Beaufort along the coast (*see* Ratynski 1983) from Alaska to the Mackenzie Delta. They are often the most abundant larvae found in ichthyoplankton sampling (Jones and Den Beste 1977). Larvae have been taken along the Tuktoyaktuk Peninsula and in the Tuktoyaktuk harbour from July to September by plankton nets, seines and trawl (*see* Ratynski 1983). The larvae apparently appear early in the spring at the higher temperatures and lower salinities above the halocline (Ratynski 1983).

Fourhorn Sculpins overwinter in bays, inlets and deltas along the coast in areas free of landfast ice (Lawrence et al. 1984; Craig et al. 1985). Overwintering fish have been taken in areas with salinities of 4.9 to 9.6 and temperatures less than 0°C (Lawrence et al 1984; Craig et al. 1985). One female was taken in Tuktoyaktuk harbour in January 1981 at a depth of 9.5 m, salinity of 22.5, and temperature of less than 0°C (Lawrence et al. 1984). While the species is known to overwinter in bays and inlets, the importance of offshore areas is not known. The habitat in the eastern Arctic has not been as well described, but one might assume that similar conditions prevail.

General Biology

McAllister (1980) reported a maximum age of 14 years for the species. Based on calculations from the Tuktoyaktuk Peninsula, age at maturity would appear to be four to five years (Craig and McCart 1976; Lawrence et al. 1984). No sexual differences in age at maturity were reported, but 70 to 88% of the midsummer catch were females in 1978 to 1980. Lawrence et al. (1984) also noted that females grew significantly faster and lived longer (up to 14 years) than males (up to 11 years). From the data presented by Lawerence et al. (1984), length (total length) at maturity was 180 mm for females and about 150 mm for males. Maximum lengths of up to 340 mm have been reported (McAllister 1980) based on data from Alaska, the Yukon and Siberia (Andriyashev 1954; Percy 1975; Griffiths et al. 1975, 1977). Similar information is not available from the eastern Arctic.

The species spawning period and habitats are not known. The species probably spawns in late winter

under the ice (Percy 1975). A ripe and running female was taken in Tuktoyaktuk Harbour in January of 1981 at a depth of 9.5 m, salinity 22.5 and temperature less than 0°C (Lawrence et al. 1984). The timing may vary with locale and may be related to variations in local winter temperature and salinity.

The eggs hatch in May to June and free swimming larvae are generally abundant in shallow pelagic areas and along the coast by July (Khan and Faber 1973; McAllister 1980; Ratynski 1983). Young-of-the-year in the Beaufort Sea grow from 19 mm in July to 38.6 m in September (Lawrence et al. 1984). Similar findings have been reported from Siberia, the Yukon and Alaska (Andriyashev 1954; Percy 1975; Griffiths et al. 1975, 1977). Juveniles were 50 mm in length by the following spring, up to 120 mm at age two, and 150 mm plus by age three (*see* Lawrence et al. 1984). Growth appeared to be slower after maturity but continued through all age classes (Lawrence et al. 1984).

Little information is available on species movements, but there are indications that Fourhorn Sculpin move to the coast from offshore areas in the spring and return offshore in the fall (Lawrence et al. 1984). These authors also reported the avoidance of freshwater plumes by Fourhorn Sculpin, but noted a tendency for it to move into coastal streams in the region of tidal influence. Fourhorn Sculpins have also been reported up to 150 km upstream in the Mackenzie (McAllister 1980), but these are probably not resident populations. Such movements may be in relation to feeding or a response to preferred temperature and salinities.

The larvae are undoubtedly planktivorous and smaller fish feed on amphipods and copepods (Craig and McCart 1976). The diet of large fish consists of isopods, amphipods, mysids and plant material; isopods and amphipods being most frequent (McAllister 1961). Lawrence et al. (1984) also found fish (Fourhorn Sculpin) and pelecypods in stomachs of fish taken from the western Arctic. Chironomid larvae, annelids, fish eggs and fish (smelt, *Elginus novaga*, and Threespined Stickleback, *Gasterosteus aculeatus*) have also been reported in stomach contents (McAllister 1961; Hansson et al. 1984). Fourhorn Sculpins of some of the freshwater and euryhaline lakes of the Archipelago islands are found in association with the isopod *Mesidosethera entomon glacialis* and that these lakes are usually devoid of freshwater fish (McAllister and Aniskowicz 1976).

Limiting Factors

The species may be susceptible to chronic trace contaminant exposure, pesticide exposure or to shifts in species composition. Hansson et al. (1984) have indicated that sublethal effects of pollutants may be responsible for a high frequency (54%) of spinal abnormalities in Fourhorn Sculpins in polluted areas of the Baltic Sea. However, it is not known if these effects are of ecological significance or if they influence the survival, reproduction or niche of the affected individuals. Such problems are as yet minimal in the Canadian range of the species, but may become more prevalent, if and when development, particularly petrochemical exploration and exploitation, intensifies. An exception is Garrow Lake, Cornwallis Island, Northwest Territories. This lake is meromictic and hypersaline. The lower, oxygen-free zone is populated by bacteria which are the forage base for the crustacea of the upper zones which dive into the lower zone to feed. These crustacea form the forage base of the lake's Fourhorn Sculpin population, the only fish in the lake. Mining waste from a nearby lead-zinc mine is being pumped into the lake to prevent pollution of the Arctic Ocean, and consequently destroying the bacteria which are the base of the food chain (Dickman 1988).

The demise of the freshwater form, *Myoxocephalus thompsoni*, in Lake Ontario has been attributed to chronic pesticide and herbicide pollution or recruitment failure as a result of predation or competition by Alewife, *Alosa pseudoharengus* (Christie 1973; Gray 1979). The Fourhorn Sculpin is apparently subject to intense predation in shallow water by gulls, waterfowl and shorebirds. The species is also eaten by whitefish (*Coregonus* sp), Arctic Char, eelpouts and other Cottidae including other members of its own species (*see* McAllister 1961).

Special Significance of the Species

The Fourhorn Sculpin is of little direct commercial or sportfishing interest, but it plays an important role in the shallow coastal Arctic ecosystem, where it is often the dominant species. It is of special interest in analysis of Canadian post-glacial dispersion patterns. It may be of value as an indicator of environmental quality due to the morphological changes that result from sublethal effects of pollutants and could be a key species to monitor in areas of development in the Arctic. Fourhorn Sculpins also provide a vital link in the Arctic marine environment in the conversion and transport of energy to higher trophic levels as it is an important component in the diet of waterfowl and fishes. Its distribution and evolution in the freshwater and euryhaline lakes of the Arctic Islands is of scientific interest and the populations should be protected in these particularly sensitive environments.

Evaluation

The Fourhorn Sculpin is common and abundant in Canadian Arctic coastal waters. More detailed

information is required on distribution, abundance, biology and ecology, but the species is secure in Canada.

Evolving populations in the freshwater and euryhaline lakes of the Arctic Archipelago are probably genetically unique and should be given special consideration. These populations are vulnerable. The population in Garrrow Lake, Cornwallis Island, is in danger of extirpation or may already have been lost.

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Status of the Spoonhead Sculpin, *Cottus ricei*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

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The Spoonhead Sculpin, *Cottus ricei*, is the most distinct North American member of the genus and on this continent is most closely related to the European *Cottus gobei* species group. The species is widespread east of the Great Divide ranging into Quebec and north to the mouth of the Mackenzie River and other drainages into Hudson and James bays. It has been recorded from all of the Great Lakes, but may be declining in Lake Erie and declining or extirpated from Lake Ontario. Elsewhere, the species is common where found and collection efforts in the 1970s have filled in many information gaps on the distribution in Ontario and Quebec. The distribution of the species appears to be closely related to glacial lakes created at the end of the Wisconsin period of glaciation. Post-glacial dispersion of the species may still be occurring as drainage systems adjust to isostatic rebound.

Le chabot à tête plate, *Cottus ricei*, est le membre le plus distinctif du genre en Amérique du Nord et, sur ce continent, est fortement apparenté au chabot de torrent, *Cottus gobei*, une groupe d'espèce d'Europe. L'espèce est largement répandue à l'est de la ligne de partage des eaux où elle atteint le Québec et, au nord, l'embouchure du fleuve Mackenzie et d'autres bassins versants de la baie d'Hudson et de la baie James. Elle a été signalée dans tous les Grands Lacs, mais pourrait bien être en déclin dans le lac Érié et en déclin, ou disparue, dans le lac Ontario. Ailleurs, l'espèce est courante dans les zones qu'elle habite et les collectes réalisées au cours des années 1970 ont permis de combler bon nombre de lacunes quant à sa répartition en Ontario et au Québec. L'espèce semble étroitement liée aux lacs glaciaires créés à la fin de la glaciation du Wisconsin. La dispersion postglaciaire de l'espèce peut ne pas être terminée, les bassins versants continuant de s'ajuster à l'équilibre isostatique.

Key Words: Spoonhead Sculpin, *Cottus ricei*, chabot à tête plate, Rice's Sculpin, Cottidae, sculpins, status, Canada.

The Spoonhead Sculpin, *Cottus ricei* (Nelson 1876), is the most distinctive member of the genus in North America and is probably most closely related to the European *Cottus gobei* species group (McAllister and Lindsey 1961). The body (Figure 1) is oddly shaped, with a flattened head and tubular trunk which is compressed laterally toward the tail. The caudal peduncle is narrow and the tail fin is slightly rounded and not forked. There are two dorsal fins, the first being smaller than the second, and a long anal fin. The pelvic fins are small and ventral while the pectorals are large and fanlike. The eyes are located on the top of the head and normal scales are lacking on the body which is more or less covered by small "prickles" which are sometimes restricted to a patch behind the pectoral fin.

These are small fish, most specimens being 4 to 6 cm in length but individuals of up to 13.4 cm have been recorded (Delisle and Van Vliet 1968; Scott and Crossman 1973). There appear to be clinal northeast variations in the number of vertebrae, fin rays, and in pigmentation (Scott and Crossman 1973; McAllister and Parker 1980). In the lower Great Lakes, the general colouration is light brown to tan, but individuals further north are decidedly darker. There may be dark, saddle-like blotches dorsally, three along the base of the second dorsal fin and one on the caudal peduncle. The remainder of the back and sides are diversely speckled with brown spots which may also be found on the dorsal and caudal fins. The remaining fins are usually clear, but may exhibit various patterns of pigmentation in some watersheds (*see* Scott and Crossman 1973).

The distribution and biology of many fishes in Canada, especially deepwater forms, are not well known. This inhibits discussion of their zoogeography and has given rise to misconceptions concerning their status. *Cottus ricei* is undoubtedly one such species. The following is a summary of the available information and an informed statement of the current status of the species.

Distribution

The North American distribution of the Spoonhead Sculpin (Figure 2) is virtually restricted to Canada. The species has been reported in all of the Great Lakes, including Lake Michigan, and from inland waters in the State of Michigan (Scott and Crossman 1973).

*Received and accepted by COSEWIC 11 April 1989 — no designation required.

FIGURE 1. Drawing of the Spoonhead Sculpin, *Cottus ricei* [from Scott and Crossman (1973) by permission].

The Canadian distribution includes the St. Lawrence River and Great Lakes drainages, islands in James Bay, the Hudson Bay and Arctic drainage to the mouth of the Mackenzie River. In North America, the species is considered to be a glacial relict, surviving glaciation in an upper Mississippi refugium and perhaps in the upper Missouri as well (McPhail and Lindsey 1970; Dadswell 1972; McAllister and Parker 1980; Crossman and McAllister 1986). The species probably moved northward with the edge of the retreating ice and is now confined mainly to Canada and the glacial lakes and rivers resulting from the retreat of the Wisconsin ice, dying out in the original parts of its range (McPhail and Lindsey 1970; Dadswell 1972).

The known eastern limit of the range appears to be the St. Lawrence River in Quebec near the Ile d'Orleans (Scott and Crossman 1973) and north to Lake Mistassini (Dadswell 1972). In Ontario, the Spoonhead Sculpin exists where there is suitable habitat, including the Great lakes, north to Lake Abitibi and the Severn River on Hudson Bay. It has been reported from brackish waters near Akimiski Island, James Bay (Keleher and Kooyman 1957; Ryder et al. 1964). The species has been reported in Lake Winnipeg and the Saskatchewan River in Manitoba and north to the Nelson River and Nueltin Lake. In Saskatchewan, Spoonhead Sculpins have been collected from the Saskatchewan River and Lakes Wollaston and Athabasca. It has a diverse distribution in Alberta where Spoonhead Sculpins have been taken from the Bow River and Waterton Lakes area in the southern part of the province. Collections from the Milk River system are questionable and have not been verified (Scott and Crossman 1973). The species extends west to the continental divide and north to the Athabasca system and Lesser Slave Lake and the Peace River below the canyon. In British Columbia, it occurs in the northeast in the Fort Nelson and Maskwa Rivers and the Peace-Laird system, east of the continental divide. There is one questionable record from the Flathead River near the U.S. border [University of British Columbia: UBC 56-577], but its presence there was not noted by Peden and Hughes (1984). This record may be of the Shorthead Sculpin, *Cottus confusus*. Spoonhead Sculpins also occur in the Yukon Territory, in the Peel-Caribou systems of the Mackenzie River basin.

In the Northwest Territories, the species has been found in the upper and lower Mackenzie River of the Arctic drainage and the Thelon River system of the Hudson Bay drainage (McAllister 1962; Scott and Crossman 1973).

Protection

There are no specific protective measures for the Spoonhead Sculpin in Canada. General protection is given under the terms of the Federal Fisheries Act or various provincial wildlife legislation. The species is listed as of special concern in Montana and as a Protected Species in New York State (Johnson 1987).

Population Sizes and Trends

The distribution and biology of many fishes in Canada are poorly known, especially where these are deepwater forms and/or not of commercial interest. Due to certain habitat preferences or particular habits, some fishes like the Spoonhead Sculpin will not be caught when collecting with standard gear. Although widely distributed across Canada, information on population sizes and trends for the Spoonhead Sculpin is generally limited to presence or absence data.

In Ontario and Quebec, the species was originally reported from all of the Great Lakes (Delisle and Van Vliet 1968; Scott and Crossman 1973) and, in a few widely scattered lakes suggesting a lacustrine habitat for this fish in southeastern Canada. During the 1970s, a series of collections by Dadswell (1972) extended the known range of the species 700 km east to the northern end of Lake Mistassini, Quebec, and added 88 new locations for the species in Ontario and Quebec, closing many gaps between previous distribution records.

In southeastern Canada, the species is found more often in lakes than in rivers and appears to be predominately lacustrine. In western Canada, the

species is more commonly found in running water (McPhail and Lindsey 1970; Dadswell 1972). The apparent difference in habitat could possibly be an artifact of sampling or because there are few glacial and modern lakes in the west. Dadswell (1972), for example, did not examine areas of running water and most western collections have not concentrated on lakes using otter trawls. It has been suggested that systematic surveys throughout Canada with adequate gear would possibly fill in more gaps in the known range. For example, the species has recently been reported from the Speed River in southwestern Ontario (Ontario Ministry of National Resources). The suggestion is, however, highly unlikely. The Speed River record could be a misidentification. This habitat difference is exhibited by other species such as *Percopsis omniscomaycus* and *Hybopsis storerianus* (Scott and Crossman 1973: 421, 681).

Dadswell (1972) has discussed the influence of light. This fish occurs in the depths of clear lakes but at shallower levels in turbid lakes. In the northwest, lakes of glacial origin are not as plentiful as in the southeast and rivers tend to be cooler.

Most collections [National Museum of Natural Sciences (now Canadian Museum of Nature (NMC), Royal Ontario Museum (ROM), Ontario Ministry of Natural Resources (OMNR)] have not shown the species to be abundant where taken. However, Dadswell (1972) found Spoonhead Sculpins to be moderately abundant in deep, stratified lakes and very abundant in the shallow, turbid lakes of the Ontario/Quebec clay belt. No other abundance information is available and most collection records are not recent; many are prior to the 1960s. Where more recent information is available from the same watersheds the presence of the species has been reconfirmed and as indicated previously, many new sites have been added.

Parker and McKee (1980) and D. E. McAllister, National Museum of Natural Sciences, Ottawa, Ontario; personal communication) indicate there may be some concern that the species has become rare or extirpated in Lake Ontario where it has not been recently collected. The species is given protected status in New York where it was known only from Lake Ontario (Johnson 1987). The Deepwater Sculpin (*Myoxocephalus thompsoni*) is now believed extirpated from Lake Ontario and has not been collected recently in Lake Erie (Scott and Crossman 1973; Gray 1979; Parker 1988). Spoonhead Sculpins in Lake Ontario may have been affected by the same factors leading to the demise of the Deepwater Sculpin. Various theories for the disappearance of the latter have been suggested including pesticide or herbicide pollution, and predation by, or competition with Alewife (*Alosa pseudoharengus*) (*see* Scott and Crossman 1973; Gray 1979). Regardless, this species, unlike the former, is widely distributed elsewhere in Ontario and low numbers or extirpation in Lake Ontario, if real, would not threaten its existence in Ontario or Canada. Reintroductions, either natural or artificial, would be possible, providing the causative factor(s) is corrected, as the species has been recorded from the Lake Ontario watershed (NMNS; OMNR; ROM). However, the species disappearance from the two lower Great Lakes should be of concern, should the same unknown factor(s) affect the other lakes.

Although many site records are based on a very few specimens, often from Lake Trout (*Salvelinus namaycush*) or burbot (*Lota*) stomachs, concentrated collection efforts have detailed a wider distribution for the species (*e.g.* Dadswell 1972). With the possible exception of Lake Ontario, and perhaps Lake Erie, the species could be more widely distributed than present records indicate and should be looked for in other areas within the known range where suitable habitat exists.

Habitat

As mentioned previously, site records led McPhail and Lindsey (1970) to postulate a riverine preference in western Canada and Dadswell (1972) to suggest a lacustrine habitat in southeastern Canada. However, this may be solely the result of collection methods and choice of sites. Many older records, for instance, are from Lake Trout or burbot stomach contents (Scott and Crossman 1973), and Dadswell (1972) did not sample in running water, although others have sampled many rivers in Ontario with similar results (McAllister, personal communication).

The species appears to be a glacial relict, the distribution being closely associated with the maximum extent of the Wisconsin glacial lakes and their outlet channels (Dadswell 1972). Dispersal some 17 000 to 6 000 years ago was by means of the post-glacial waters north and east from a Mississippian refugium, the species dying out in southern parts of the range (McPhail and Lindsey 1970). Spoonhead Sculpins have dispersed somewhat beyond the glacial lake-marine areas and may be still dispersing (Dadswell 1972) as drainages adjust to isostatic rebound plus stream capture or headwater piracy.

Spoonhead Sculpins may be tolerant of turbid and brackish waters (Scott and Crossman 1973; McAllister and Parker 1980) but are usually taken in small swift streams, rivers and lakes (Scott and Crossman 1973). Depth preferences are not clear but are probably intermediate between those of the Deepwater Sculpin (*Myoxocephalus thompsoni*)

FIGURE 2. Distribution of the Spoonhead Sculpin, *Cottus ricei*, in Canada.

and the Slimy Sculpin (*Cottus cognatus*) in the Great Lakes (Scott and Crossman 1973), but depth is probably mediated by temperature and light (= water clarity). Deason (1979) gave a range for Lake Michigan from shore to about 140 m which appears to be most realistic (Scott and Crossman 1973).

Delisle and Van Vliet (1968) found Spoonhead Sculpins in June and July, on the bottom from 17 to 27 m, in Henry Lake, Gatineau County, Quebec, at temperatures of 6.0 ot 7.2°C. In Pemichangan Lake, Gatineau County, 12 Spoonhead Sculpins were taken at a depth of 42.4 m by the same authors in August at a temperature of 4.5°C. Dadswell (1972) reported that in deep, stratified lakes, the species was found at depths ranging from 5 to 50 m with a temperature range of 4 to 8°C. In shallow turbid lakes (Dadswell 1972), Spoonhead Sculpins were abundant at depths of 5 to 10 m with temperatures up to 18°C.

General Biology

Very little is known concerning the biology of the species. Scott (1967) considered the Spoonhead Sculpin to be a spring spawner. However, Delisle and Van Vliet (1968) suggested spawning in late summer or autumn. Ovaries examined from Ontario specimens support the latter view (Scott and Crossman 1973). Larvae of the family (Cottidae) have been described by Heufelder (1982).

These fish are relatively small; most specimens are in the range of 4 to 6 cm (Scott and Crossman 1973). Specimens larger than 7 cm have been reported and it may be that smaller individuals are immature (Scott and Crossman 1973). Specimens of up to 10.2 cm have been taken in Lake Erie. The largest recorded specimen, 13.4 cm, was taken in Penichangan Lake, Quebec (Delisle and Van Vliet 1968).

No information is available on species movements or diet. Scott and Crossman (1973)

assumed that planktonic crustaceans and aquatic insect larvae would be important food items as for the Deepwater Sculpin (McAllister 1961; McPhail and Lindsey 1970).

The parasitic fauna of the species is not known but the Spoonhead Sculpin is known to be important in the diet of Lake Trout and burbot (Deason 1939; Rawson 1959) and perhaps whitefish (Deason 1939).

Limiting Factors

The historical limiting factors for the Spoonhead Sculpin would appear to be the availability of Wisconsin glacial lakes, their outlet channels and interconnecting waterways. The species may be susceptible to chronic trace contaminant exposure, or to shifts in species compositions in the deepwater community, as indicated for the Deepwater Sculpin (*see* Parker 1988), but this remains to be shown. Habitat changes and degradation due to silting, etc., may be limiting distribution in southwestern Ontario.

Special Significance of the Species

The species is of little direct interest to the commercial or sport fisheries, but indirectly it is of interest as it is a traditional natural food of Lake Trout and burbot (Scott and Crossman 1973).

Spoonhead Sculpin are also of special interest to the scientific community since the distribution provides information on the geological or glacial history of the region and an indication of environmental conditions.

Evaluation

The Spoonhead Sculpin is widely dispersed throughout the country. With the possible exception of Lake Ontario, and perhaps Lake Erie, regional populations are common where found. Additional information is required to establish the situation in Lakes Ontario and Erie.

Acknowledgments

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Status of the Bering Wolffish, *Anarhichas orientalis*, in Canada*

J. HOUSTON[1] and D. E. MCALLISTER[2]

[1]374 Fireside Drive, Woodlawn, Ontario K0A 3M0
[2]Canadian Museum of Nature, Ottawa, Ontario K1P 6P4

Houston, J., and D. E. McAllister. 1990. Status of the Bering Wolffish, *Anarhichas orientalis*, in Canada. Canadian Field-Naturalist 104(1): 20–23.

The Bering Wolffish, *Anarhichas orientalis*, has a spotty distribution in the northwest Pacific Ocean, and the Bering Sea. The species has been recorded at one location in the Canadian Arctic from Bathurst Inlet. Very little is known on the biology and ecology of these fish and its shallow water habitat which are unusual among the members of the Anarhichaidae. The species should be considered vulnerable in Canada.

Le loup de Béring, *Anarhichas orientalis*, présente une aire de distribution sporadique dans le nord-ouest du Pacifique et dans la mer de Béring. Cette espèce a été observée en un seul endroit de l'Arctique canadien, l'inlet Bathurst. On connaît très peu de choses sur la biologie et l'écologie de ce poisson qui est rare parmi les Anarhichadidés dans leur habitat en eau peu profonde. L'espèce doit être considérée vulnérable au Canada.

Key Words: Bering Wolffish, *Anarhichas orientalis*, Loup de Bering, Anarhichadidae, wolffishes, arctic marine, rare and endangered fishes, status, Canada.

Wolffishes (Anarhichadidae) are large blenny-like fishes of the deep, cold waters of the continental shelves of the Pacific, Arctic and Atlantic oceans. They have a generally laterally compressed and elongated shape tapering to a slender caudal peduncle. The body is usually naked or with a few small cycloid scales, the lateral line may be absent or reduced and pelvic fins are absent. These fish have strong conical canine teeth and molars (McClane 1978; Nelson 1984).

The Bering Wolffish, *Anarhichas orientalis* (Pallas 1814), [Figure 1] differs from the five other species of the genera in having 53 or more anal rays, deeper more rounded caudal fins, and is found only in the North Pacific and western Arctic oceans (McAllister, unpublished manuscript, *Marine Fishes of the Canadian Arctic*). The vomerine row of teeth is also larger than the palentine rows and extends beyond the latter, the upper lip is wrinkled and not papillate.

Members of the species have a short blunt head and steep snout with large canine teeth pointing forward from the end of the jaws. The body is long and compressed with small cycloid scales scattered over the surface. The lateral line canal and pores are absent, but there are instead three rows of neuromasts, a short predorsal row, a dorsolateral row extending to the pectoral and a short ventral row (McAllister, *unpublished*). The dorsal fin is long and curves down to the short, rounded caudal fin. The anal fin is also long and narrowly united with the caudal fin at the base, the pectorals are broad and oval in shape (*see* Barsukov 1959; McAllister, *unpublished*). The species is known to reach lengths of up to 12 cm and weigh from 3 to 15 kg (Barsukov 1959). Bering Wolffish are reported to be dark brown in colour and usually without dark spots or stripes (Andriyashev 1954). Young fish may have horizontal lines on the back and dark spots on the head (Andriyashev 1954; McAllister, *unpublished*).

The species is known from only one region of western Arctic Canada and has not been recorded elsewhere in the Canadian Arctic. Not only is the distribution limited but the species is apparently not abundant (Smith 1977). The following report on the species was prepared for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to outline the status of this species in Canada.

Distribution

The known distribution of the species is spotty; the range is the northwestern part of the Pacific, The Gulf of Tatary, the Sea of Okhotsk, the Bering Sea north to Norton Sound near the Bering Strait, and in Bathurst Inlet in the western Canadian Arctic (Figure 2). The species is not found along the Pacific coast of North America (Andriyashev 1954; Barsukov 1959; McAllister, *unpublished*).

Protection

No specific legislation is in place in any part of the known range. In Canada, general protection is

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

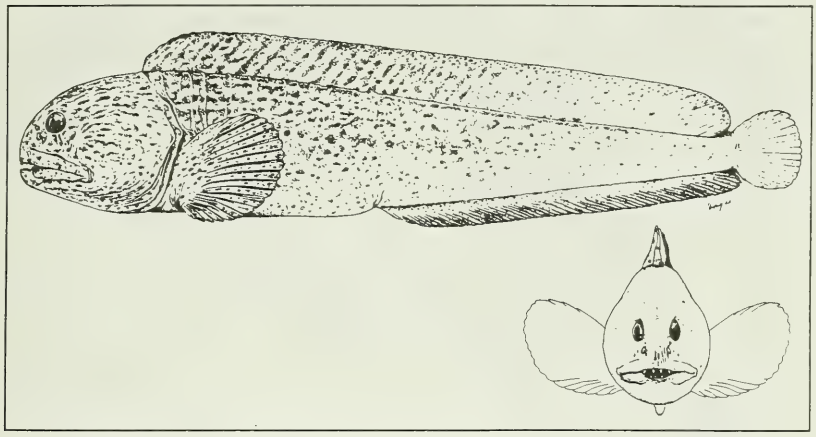

FIGURE 1. Illustration of the Bering Wolffish, *Anarhichas orientalis* (drawing by C. Douglas, courtesy D. E. McAllister, Canadian Museum of Nature).

potentially available under the Habitat Section of the Fisheries Act.

Population Sizes and Trends

Very little information is available on the abundance of this species except for presence/absence data. Andriyashev (1954) and Barsukov (1959) indicate that the species is common in the northwestern Pacific and Bering Sea. However, it cannot be that abundant as it is considered of no economic interest, whereas other species of the genus are exploited by the commercial fisheries (Andriyashev 1954).

There are only three records (Canadian Museum of Nature collections) for the species in Canada (Figure 3), although wolffish (either *Anarhichas orientalis* or *Anarhichas denticulatus*) are known to Inuit of the area as the old womanfish (Smith 1977). The known distribution of the species is spotty and raises the question as to whether this represents a dependence on localized ecological conditions or whether normal collection gear are unsuccessful in capturing them (McAllister, *unpublished*). As they are not well known to the Inuit of the area it is more likely that the former is the case, as a species with these characteristics would have been known to, and reported by the Inuit. In addition, fairly intensive sampling programs have been undertaken by various agencies (Fisheries and Oceans, Canadian Museum of Nature, and various consultants in response to the requirements for environmental impact assessments in relation to oil and gas exploration and development), especially in the shallower waters of the western Canadian Arctic (Hunter et al. 1984) and these have failed to turn up specimens elsewhere in the Canadian Arctic.

FIGURE 2. General distribution of Bering Wolffish populations.

Habitat

Bering Wolffish are not a well-studied species. Very little is known of their habitat. The species is usually found in shallower waters than the other members of the genus and seems to prefer coastal areas with algae covered rocky bottoms. They apparently keep to the shallower coastal areas from spring to late fall, moving offshore when the coast is ice-bound (Andriyashev 1954).

The species would appear to be benthophagic (Barsukov 1959), feeding on crabs and molluscs. Their habits may restrict their distribution to highly localized sites where suitable conditions are available i.e., shallower water, warmer temperatures. The species is likely not found in the eastern

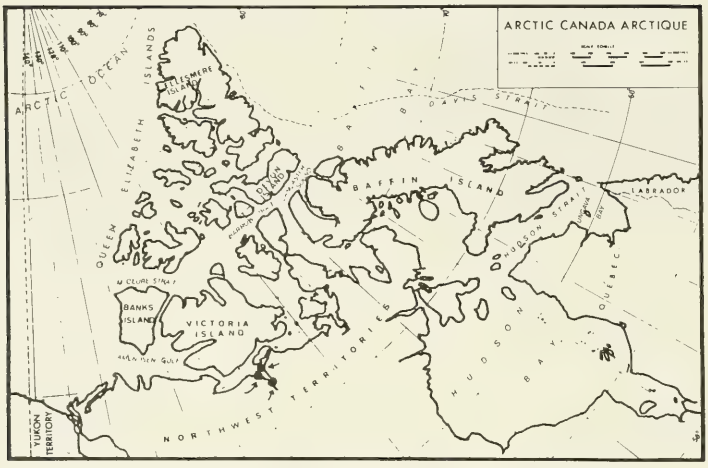

FIGURE 3. Canadian collection records for the Bering Wolffish.

Arctic because the waters of the nearshore areas are generally deeper and colder.

General Biology

The biology of the species is virtually unknown. One large female (1.12 m) with well-developed eggs was taken in late May from Avachinskaya Bay, Kamchatka (Andriyashev 1954). Barsukov (1959) reported egg diameters at 4.0 to 4.5 mm. The larvae are apparently pelagic and an individual of 19 mm in length was once cast aboard a ship during a storm in May in the Bering Sea (Andriyashev 1954). Kobayashi (1961) described young fish of the species based on two specimens collected from the Okhotsk Sea in June of 1957 and August 1958, respectively.

Maturity may be reached at 15 to 17 cm, a fish of 41 cm was aged at 4+ years, one at 70 cm at 8+ years and a 112 cm female at 17+ years (Barsukov 1959).

The species is a bottom dweller and although the diet has not been well studied, crabs and mussels are known to be important food items (Andriyashev 1954).

Limiting Factors

Not known, however habitat requirements may be very narrow and thus limit distribution of the species.

Special Significance of the Species

The species is currently of little or no economic importance. Smith (1977) indicates that the Bering Wolffish may be a forage species for arctic seals. Dunbar (1970) suggests that wolffish are excellent to eat and that the hide could be tanned for commercial sale. However, the two Arctic species, *Anarhichas orientalis* and *Anarhichas denticulatus* have a very narrow range and are probably not abundant (Leim and Scott 1966; Dunbar 1970). Dunbar (1970) has also pointed out that the fishing potential of arctic waters is negligible so even if further populations are found in the Arctic there is little likelihood that the species would ever be found in commercial abundance.

Evaluation

Very little is known of this species in Canada or elsewhere. The Canadian distribution is limited and the species is probably not common in Arctic waters. Bering Wolffish are a naturally rare species in Canadian waters. The species should be considered vulnerable due to its narrow distribution in the western Canadian arctic.

Acknowledgments

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Status of the Blackline Prickleback, *Acantholumpenus mackayi*, in Canada*

J. HOUSTON[1] and D. E. MCALLISTER[2]

[1]374 Fireside Drive, Woodlawn, Ontario K0A 3M0
[2]Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Houston, J., and D. E. McAllister. 1990. Status of the Blackline Prickleback, *Acantholumpenus mackayi*, in Canada. Canadian Field-Naturalist 104(1): 24–28.

The Blackline Prickleback, *Acantholumpenus mackayi*, is one of the larger eelblennies of the North Pacific and Arctic oceans. The Canadian range probably represents the northeastern fringe of the range and is limited to the Beaufort Sea in the vicinity of the Tuktoyaktuk Peninsula. The species is probably euryhaline, benthophagic and found over sand, mud or silty bottoms at depths to 60 m. Very little is known of the biology of the species, especially in Canadian waters where it is rare and vulnerable. The future of these fish in Canada is threatened by possible habitat loss or degradation through activities connected with the exploration and development of hydrocarbon deposits in the area.

Le terrassier à six lignes, *Acantholumpenus mackayi*, est l'une des plus grosses lompénies de l'océan Pacifique Nord et de l'océan Arctique. L'aire de répartition canadienne se situe probablement à la bordure est de l'aire de répartition globale et est limitée par la mer de Beaufort dans les environs de la péninsule de Tuktoyaktuk. Il s'agit probablement d'une espèce euryhaline, benthophage qu'on trouve sur des fonds sableux, vaseux ou limoneux à des profondeurs de 60 m. Sa biologie reste très mal connue, notamment dans les eaux canadiennes où l'espèce est rare et vulnérable. L'avenir de ce poisson au Canada est menacé par la perte ou la dégradation possible de son habitat à cause des activités associées à l'exploration et à l'exploitation des dépôts d'hydrocarbures dans le secteur.

Key Words: Blackline Prickleback, *Acantholumpenus mackayi*, terrassier à six lignes, Spiny Eelblenny, Stichaeidae, lumpeniids, eelblennies, arctic marine fishes.

The Blackline Prickleback, also known as the Spiny Eelblenny, *Acantholumpenus mackayi* (Gilbert 1893), is the only member of this genus of the prickleback family (Stichaeidae). Stichaeids are benthic fishes of the North Pacific, although a few genera are found in the Arctic and North Atlantic. The pricklebacks are not of importance in commercial or sport fisheries. They are usually rare, inhabiting deeper waters to depths of 1800 m or more, although some species may be found in intertidal areas (McClane 1978). Many of the species are small, but the Blackline Prickleback (Figure 1) may reach total lengths of 50 to 70 cm (McAllister, *unpublished manuscript*: The Marine Fishes of Arctic Canada). *Acantholumpenus mackayi* occurs in the Arctic and North Pacific oceans. The species was originally described by Gilbert (1895) as *Lumpenus mackayi* from specimens taken near Nushagak, Alaska and named for C. L. MacKay, a promising young, American ichthyologist who drowned at Nushagak in Bristol Bay in 1883 (McAllister, *unpublished*).

The species differs from other members of the prickleback family in its pointed snout which projects beyond the upper lip. In addition, there are a greater number of dorsal spines (69 or more). There is a solid dark line along the base of the dorsal fin which does not exist in other members of the family (McAllister, *unpublished*). The body is long and slender and the dorsal fin extends almost the entire length of the body narrowly uniting with the caudal fin. The pelvic fins are thoracic, slender and short with one sharp spine; the pectorals are also well forward, but larger and oval shaped. The anal fin is also long and extends to the caudal fin with which it narrowly unites.

Blackline Pricklebacks are yellowish to yellowish-brown with dark markings on the head and back. There is a more-or-less continuous dark band at the base of the dorsal fin and dark spots and lines on both sides of the lateral line; these disappear on the posterior third of the body. The fins are clear except for the caudal fin which is dark with a light posterior border (Gilbert 1895; Abe 1972; McAllister, *unpublished*).

Distribution

The known distribution of the species is broken into three disjunct regions, each separated by over 1600 km of open ocean (Figure 2). One area of the range is from the Sea of Japan to the Okhotsk Sea, another is the southern and eastern Bering Sea and the third is the Canadian Arctic (Legendre et al.

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

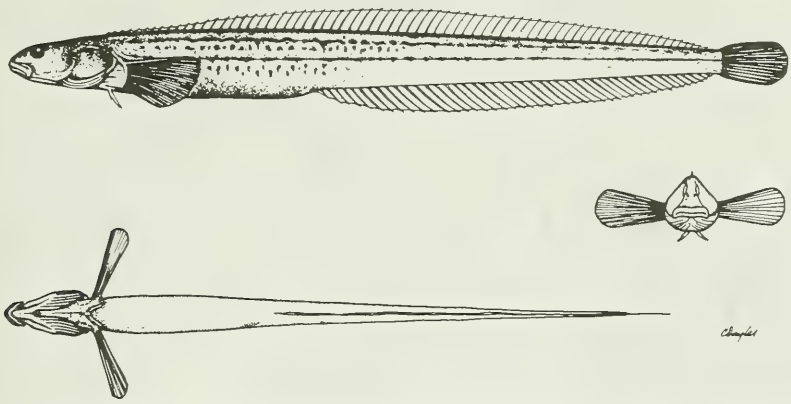

FIGURE 1. Blackline Prickleback, *Acantholumpenus mackayi*, NMC65-0341-C, lateral, frontal and ventral views (drawing by C. Douglas, courtesy D. E. McAllister, Canadian Museum of Nature).

1975) in the Beaufort Sea (Figure 3), and Mackenzie Delta in the area of Tuktoyaktuk (Lindberg and Krosyukova 1975; Shchetinnikov 1983; McAllister, *unpublished*). Surveys to locate the species in eastern Kamchatka, the western Bering Sea, northern Alaska, the Yukon and elsewhere in the Northwest Territories have not produced evidence of intervening populations (McAllister, *unpublished*). Canadian populations probably represent the northeastern end of the species range.

Protection

No specific legislation exists for the protection of these fish in any part of the range. In Canada, general potential protection is available through the Habitat Section of the Fisheries Act.

Population Sizes and Trends

Very little information other than presence or absence data is available for this species. In Russian waters, the species has been reported in small numbers (Makuskov 1971; Shchetinnikov 1983). Schetinnikov (1983) reported that the Blackline Prickleback is common in near-bottom waters of the Gulf of Terpenium around Sakhalin Island. Maximum population density was 50 to 720 fish per km^2 at depths of 20 to 50 m in the northern and central areas of the Gulf, but became less abundant towards the southeast and toward the coast (Shchetinnikov 1983).

Similar information from Alaska and Canada is not available. Canadian Museum of Nature (NMS) collection records for Canadian specimens suggest that the species is not abundant in Canadian waters. Galbraith (1975) reporting on fish population surveys of the coastal Beaufort around Tuktoyaktuk Peninsula reported only two lumpenins from bottom otter trawls and less than 100 from mid-water trawls. Ratynski (1983) reported only eight larvae from a series of trawls in 1982 (Blackline Prickleback and Slender Eelblenny, *Lumpenus fabricii*). These collections are the first records of lumpenin larvae in the Beaufort Sea and none were taken outside the harbour in Kugmallit Bay (Ratnyski 1983). Ratynski (1983) suggested that at the time of year of sampling, lumpenin samples may have been low as the larvae may have been large enough to avoid the nets or had moved from the area.

Habitat

Canadian specimens have been collected on mud bottoms at an average depth of 13 m (McAllister,

FIGURE 2. General distribution of the Blackline Prickleback, *Acantholumpenus mackayi*.

FIGURE 3. Canadian distribution of the Blackline Prickleback, *Acantholumpenus mackayi*.

unpublished). In Alaska, it has been taken at the mouth of the Nushagak River to a depth of 56 m (Schmidt 1950). The species is most abundant in the Gulf of Terpenium at 29 to 50 m over sandy and silty bottoms; it has also been taken from brackish waters in lakes of northern Hokkaido and the estuary of the Amur River (McAllister, *unpublished*). The species thus appears to be tolerant of brackish waters but is likely euryhaline as salinities in the Gulf of Terpenium and the Aleutians would be expected to be high (McAllister, *unpublished*). Larval specimens were taken in Tuktoyaktuk Harbour in the upper halocline at depths of 4.0 to 7.5 m (Ratynski 1983) in cooler more saline waters.

Shchetinnikov (1983) suggested that spawning areas are located in shallower waters. Ratynski (1983) indicated that the cooler saline bottom layers of Tuktoyaktuk Harbour may be of critical importance for spawning of the Canadian populations.

The body shape, frequency of catch in bottom trawling, and food composition all indicate that the Blackline Prickleback is benthic, feeding on the bottom and rarely in the water column near the bottom (Shchetinnikov 1983). Shchetinnikov (1983) also indicated that the species is non-schooling.

General Biology

Information on the biology of the species is limited. Ratynski (1983) reported that females taken in Tuktoyaktuk Harbour in September 1982 were nearly ripe and females collected in August of 1971 had eggs 1.0 to 1.4 mm in diameter (McAllister 1975). Shchetinnikov (1983) indicated that males and females collected in July of 1978 in the Gulf of Terpenium were in post-spawning condition. Both Ratynski (1983) and Shchetinnikov (1983) suggested that the fish move into shallow water to spawn and the younger fish remain in deeper waters to feed.

In the Gulf of Terpenium, males and females mature at a length of 30 to 40 cm and maximum length was found to be 62 cm (Shchetinnikov 1983). McAllister (*unpublished*) suggested that males tend to be larger than females but Shchetinnikov (1983) found the reverse to be the case in the Gulf of Terpenium. In Canadian waters, the largest individual taken weighed 109 g and measured 49.4 cm (McAllister, *unpublished*). In Soviet waters, they may grow to 58.5 cm and up to 70 cm off Japan (Ueno 1971). Based on the relatively low number of fish recorded it is not possible to make inferences as to taxonomic differences, but it does appear that fish from Japan may be larger, have more vertebrae, dorsal spines and rays and could represent a species or subspecies distinct from *Acantholumpenus mackayi* (McAllister, *unpublished*).

Larval stages and growth have been outlined by Tokuya and Amaoka (1980). Larval lumpenids captured in July of 1982 at Tuktoyaktuk ranged in length from 15.8 to 21.5 mm (Ratynski 1983). Tokuya and Amaoka (1980) reported juvenile lengths at 36.0 to 38.5 mm in June off Hokhaido, Japan.

Blackline Pricklebacks are typical benthophages, but in spite of their large size they have a small mouth and prey on smaller organisms. McAllister (*unpublished*) found that specimens taken in Canadian waters had been feeding on small clams 2 to 7 mm in length. Shchetinnikov (1983) reported that the species is not selective but feeds on all benthos of suitable size. The principal food items are sedentary and of limited mobility, mainly polychetes, gammarids and bi-valve molluscs. Camaceous gastropods and nudibranch molluscs are also included in the diet as are euphausids and young sea urchins (Shchetinnikov 1983). Their specialized feeding on smaller prey permits the species to avoid competition with more active benthophages such as flounders (Shchetinnikov 1983).

Limiting Factors

The species is of no economic importance and is not subject to exploitation except in Japan where they are used to make fish cakes and pastes (McAllister, *unpublished*). No other limiting factors are known for the population. However, perturbations in its near shore environment could have deleterious effects on spawning habitat and nursery areas of the larvae. In Canada, the species is not abundant and has been recorded only from the Mackenzie Delta in the region of Tuktoyaktuk Harbour which is also the centre of hydrocarbon exploration and development in the western Canadian Arctic. Dredging and drilling activities and vessel traffic in that harbour could very well be threatening to the continued existence of the species in Canadian water.

Special Significance of the Species

The Blackline Prickleback is the only species in the genus. These fish are found only in the North Pacific and western Arctic oceans. The species is larger than many of the other lumpenids and lives in shallower waters. It is of no economic importance in Canada but is of interest due to its presence here, probably at the eastern fringe of its range. The three populations are disjunct and separated by over 1600 km of open ocean. There is some indication that the most southwestern population in the Sea of Japan may be a distinct species or sub-species (McAllister, *unpublished*). If so, this would make the Canadian populations more unique. A detailed taxonomic study is required as perhaps all three populations are distinct.

Evaluation

The following factors are important in evaluating the status of this species in Canadian waters: (1) It has only been recorded, in Canada, in the Beaufort Sea in the area of the Mackenzie Delta; (2) The three populations of the species are disjunct, separated by some 1600 km of open seas. Each may be distinct; (3) The Canadian population probably represents the northeastern end of the range; (4) Except for the population of the Sea of Japan, these fish are not economically important; (5) The known Canadian range is in an area where the habitat is threatened by exploitation and development of hydrocarbon deposits.

Although there are indications of reproductive success in the Canadian populations, numbers appear to be low, and based on this and the above, the species is deemed to be extremely rare and therefore vulnerable in Canada.

Acknowledgments

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Status of the Margined Madtom, *Noturus insignis*, in Canada*

CHERYL D. GOODCHILD

2168 Harcourt Crescent, Mississauga, Ontario L4Y 1W1

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The Margined Madtom, *Noturus insignis*, is classified as threatened in Canada. In the early 1970s, it was first reported from isolated areas of the Ottawa River drainage in Ontario and Quebec, disjunct from the extreme northern fringe of its range in the United States. Its occurrence in Canada may be the result of accidental introduction of baitfish by anglers or of dispersal from New York State through the St. Lawrence River watershed. The population may be declining as attempts to recapture Margined Madtom in the 1980s were largely unsuccessful despite exhaustive sampling. Low numbers, fluctuations in spawning success and extremely specialized habitat requirements make this species' continued existence in Canada particularly perilous.

Le chat-fou lisère, *Noturus insignis*, doit être classé parmi les espèces menacées au Canada. Au début des années 1970, ce poisson a été pour la première fois signalé dans des zones isolé, du bassin versant de la rivière des Outaouais en Ontario et au Québec, ce qui marque donc une discontinuité par rapport à la limite la plus septentrionale de son aire de répartition aux Etats-Unis. Cette espèce a peut-être été introduite accidentellement au Canada comme poisson d'appât utilisé par les pêcheurs sportifs ou bien elle s'est dispersée à partir de l'État de New York à travers le bassin versant du St-Laurent. La population de cette espèce est peut-être en train de décliner puisque, dans les années 1980, on n'a pas bien réussi à recapturer le chat-fou lisère malgré les travaux d'échantillonnage exhaustifs. Le petit nombre de ces poissons, les fluctuations dans la réussite de la ponte et les conditions très spéciales qu'exige leur habitat rendent cette espèce particulièrement vulnérable.

Key Words: Margined Madtom, *Noturus insignis*, chat-fou-lisère, catfishes, Ictaluridae, madtoms, rare and endangered fishes.

The Margined Madtom, *Noturus insignis* (Richardson 1836), is a small ictalurid first reported from Canada by Rubec and Coad (1974). Although common in the upland Atlantic drainage of the United States, it has a very restricted distribution in Canada and occurs only in a few streams in the Ottawa River drainage.

These fish (Figure 1) are slate-gray or yellowish shading to pale cream on the lower head and belly. There is a bridge of pigmented skin across the belly in front of the pelvic fins and the chin is dark in front of the barbels (Smith 1985). The margins of pectoral, anal, dorsal and caudal fins frequently have a dark band. The body is elongate, caudal peduncle deep, and head depressed. They are also distinguished by short teeth on posterior edges only of pectoral spines; lower jaw included; square caudal fin. Adults commonly attain 100 mm standard length (SL) with a specimen of 126 mm SL recorded from Virginia (Taylor 1969). Keys to identify the species in Canada are found in Rubec and Coad (1974) and Coad (1986).

Distribution

North America: The zoogeography and distribution of the species in the genus *Noturus* was discussed comprehensively by Taylor (1969). The greatest number of species of *Noturus* occur in upland regions of the east central United States. Because of favourable habitat, a band from Arkansas through Kentucky and Tennessee to Virginia and North Carolina was probably a refuge during Pleistocene glaciation for several northern species of *Noturus*. This may represent the center of their evolution and it appears most species were not materially affected by glaciation. *Noturus insignis*, an upland species, was probably restricted southward by the Piedmont Plateau in Georgia and South Carolina, but has successfully moved northward again.

The native range of *Noturus insignis* includes part of the Lake Ontario drainage, from the Finger Lakes region southward through the Appalachian Highlands (Figure 2). This includes most of the Atlantic coastal streams from New York to Georgia, where they are most frequently found at or above the Fall Line†. Historical evidence points to the absence of *N. insignis* from the Upper Ohio and Tennessee systems (Figure 2).

In recent years, *Noturus insignis* has been collected from the upper Ohio River system and from the Tennessee system where it is well

*Threatened status approved and assigned by COSEWIC 11 April 1989.

†The Fall Line is the line joining waterfalls on a number of approximately parallel rivers. In the eastern United States, it refers to the line running along a sharp increase of slope from the Atlantic Coastal Plain to the Appalachian Mountains.

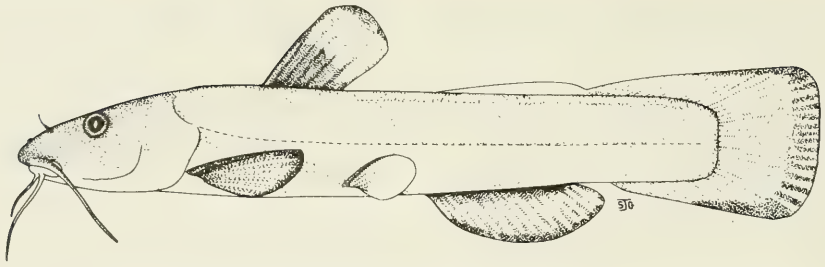

FIGURE 1. Drawing of Margined Madtom, *Noturus insignis* (drawing by C. Douglas, courtesy D. E. McAllister, Canadian Museum of Nature).

established. It is known from several localities in the Watauga drainage in North Carolina and from the North Fork of the Holston River, Virginia. It has been collected from three localities in the Monongahela and Youghiogheny system in West Virginia, Maryland, and Pennsylvania. Hocutt et al. (1986) regard *Noturus insignis* as native to the Monongahela drainage.

Noturus insignis has entered the Mississippi and Great Lakes drainages by relatively recent stream changes or human introduction. Changes in drainage pattern may account for dispersal into the Holston drainage but apparently do not account for its appearance in other drainages.

Madtoms are often used as bait by anglers. Since they are hardy and able to survive injury, disposal of unwanted bait specimens could have started new populations in areas with favourable habitat. The Margined Madtom has undoubtedly been introduced into Clark Lake, Gogebic County, Michigan (UMMZ 186551) and presumably into the Merrimack River of New Hampshire (Taylor 1969). Schmidt (1986) suggests the Merrimack drainage population of *Noturus insignis* could be native but since there are no recorded populations between the Merrimack and Hudson he suggests the argument is less convincing than for *Noturus gyrinus*, which has a similar distribution.

One of the ecological factors which seems to contribute to the present distribution of *Noturus insignis* is the availability of well-oxygenated water sufficiently warm for reproduction. Although *Noturus* species commonly avoid cold water, *Noturus insignis* may occur in salmonid streams indicating a higher tolerance for cold water.

Canada: Since *Noturus insignis* was not found in Canadian waters prior to 1971, it was excluded from the first edition of *Freshwater Fishes of Canada* by Scott and Crossman (1973) but is mentioned briefly in the notes of the 1979 reprint.

In August 1971, four specimens were collected in a stream draining Lac à la Loutre to Lac Lapêche, in Gatineau Park, Quebec, 45 km northwest of Ottawa. An additional 25 specimens were collected at the same location in November 1971 (Figure 3). This location was more than 201 km (125 air miles) north of its previously known limit in New York State (Rubec and Coad 1974). These collections are catalogued at the Canadian Museum of Nature (NMC), at Ottawa [NMC 73-0142, NMC 74-0004].

In May 1976, a single specimen of *Noturus insignis* was identified in an Ontario Ministry of Natural Resources (OMNR) collection from the Fall River, Lanark County, Ontario, 85 km southwest of Ottawa (Figure 3). Since this was the first reported occurrence of this species in Ontario,

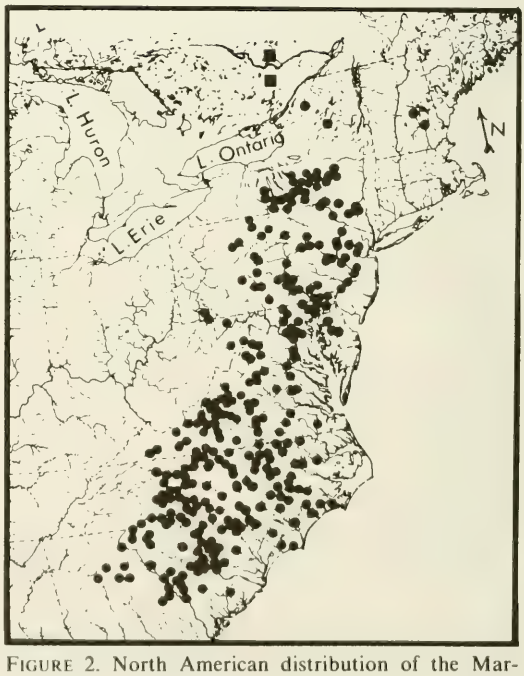

FIGURE 2. North American distribution of the Margined Madtom, *Noturus insignis*. Squares represent the disjunct Canadian populations (*adapted from* Lee et al. 1980).

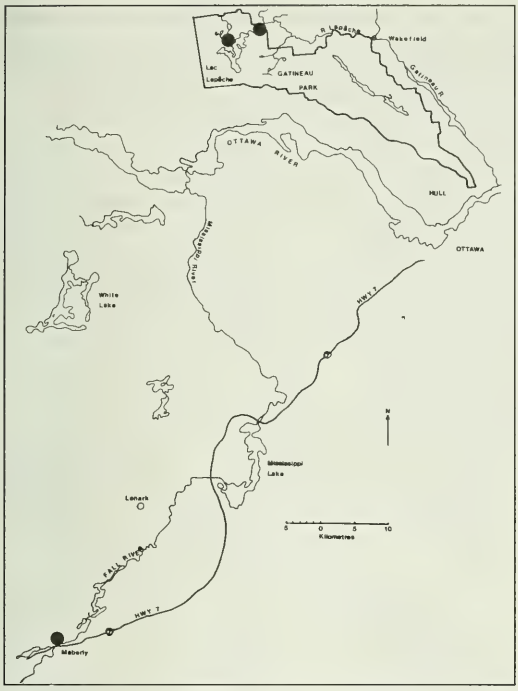

FIGURE 3. Distribution of the Margined Madtom, *Noturus insignis*, in Ontario and Quebec.

OMNR crews returned to the Fall River to determine the extent of a Margined Madtom population (G. A. Goodchild, Fisheries Branch, Ontario Ministry of Natural Resources, Queen's Park, Toronto; personal communication). On June 17, an additional 14 specimens were collected in the Fall River by electrofishing (one specimen was found dead on the banks). Thirteen of these fish are catalogued in the Royal Ontario Museum (ROM) collection [ROM32581].

Since there are well-documented introductions of *Noturus insignis* into streams in the United States, it is possible that its occurrence in Canada may also be explained by the release of baitfish by anglers. The two areas in Canada where Margined Madtoms have been found (Figure 4) are both popular areas for sport fishing and both are in or adjacent to large parks, Gatineau Park, in Quebec, and Silver Lake Provincial Park, in Ontario.

Bailey and Smith (1981) felt that *Noturus insignis* entered the Great Lakes Basin by introductions and not by post-glacial dispersal or recent immigration through canals and water course alterations. Although Taylor (1969) suggested that *Noturus insignis* entered the Great Lakes drainage by relatively recent stream changes or human introductions, he hypothesized that the relatively northern *Noturus flavus* utilized post-glacial stream changes to enter the Great Lakes at a number of points.

McAllister and Coad (1974) suggested that presence of Margined Madtom in Canada may represent either a relict population originating from the Atlantic Coastal plain, indicative of a formerly wider range, or an introduction. McAllister (1987) pointed out that *Noturus insignis* was now recorded in western New York state, only 130 km from the Canadian record in the Gatineau basin and suggested it is plausible that the Canadian occurrence is natural. Crossman and VanMeter (1979) considered that early records from small tributary streams in the Oswego River, New York and records from the tributary of the Ottawa River, could indicate the presence of isolated populations in the extreme eastern part of the Lake Ontario watershed. Margined Madtom have been reported from Oswego Country, New York as recently as 1985 (McAllister 1987).

During the final retreat of the Wisconsin ice sheets from the Gatineau area, the Champlain Sea overlaid the area of the present Gatineau, Rideau, Ottawa, and St. Lawrence rivers, Lake Champlain and the Hudson River. Although the initial stages of the Champlain Sea were marine, evidence indicates a fresh-water drainage was initiated about 10 000 years ago (Romanelli 1975; McAllister and Coad 1974). Lake Frontenac was of relatively short duration in the Ottawa area but this postglacial lake was confluent with glacial Lake Iroquois (Lake Ontario) and glacial Lake Vermont (present Lake Champlain). It provided a corridor by which dispersal could have taken place in the Ottawa Region (Rubec 1975). Also, rapid warming conditions at that time led to a warmer climate than exists today, allowing warm water species into the region by way of the Ottawa River (Rubec 1975). The final connection between the Ottawa River and the Great Lakes disappeared 4000 years ago and from that time until the construction of the Rideau Canal in the early 1800s, dispersal was restricted to ascending the Ottawa River (McAllister and Coad 1974).

Extremely limited population numbers may cast some doubt on the theory that *Noturus insignis* became established in the Ottawa River drainage during post-glacial events. These numbers may, however, be a reflection of inadequate suitable habitat. Similar disjunct records are known from New York State and New Hampshire. Additionally, the paucity of Ottawa records may reflect the lack of suitable collecting techniques.

The possibility that the Margined Madtom is a canal immigrant cannot be completely ignored. In New York State, the construction of many canals has considerably altered the distribution of fish species within the state (Smith 1985). Disjunct

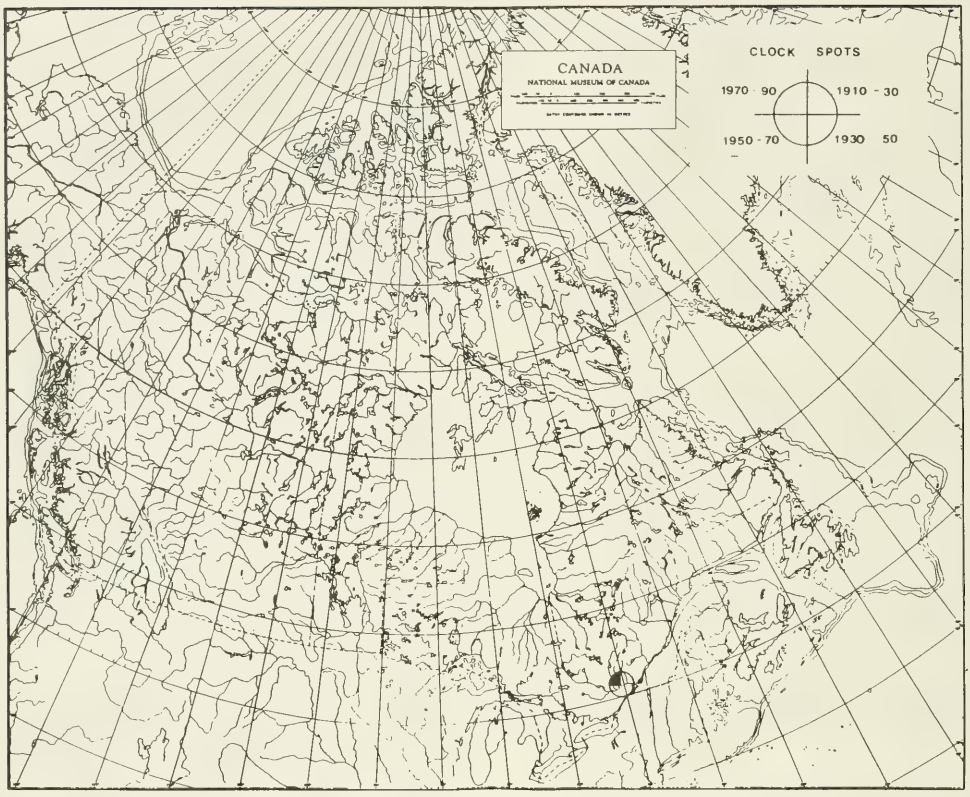

FIGURE 4. Distribution of *Noturus insignis* (eastern Ontario and western Quebec).

distribution points in the St. Lawrence River drainage of New York State are indicated on the distribution maps for Margined Madtom in Smith (1985) and Lee et al. (1980), but not explained (Figure 2). Recent dispersal of Margined Madtom to other new locations, such as their entry into the East River in West Virginia, is well documented (Stauffer et al. 1975). Yet, the waterfall at Wakefield on the lower Rivière Lapêche appears to be an effective barrier to the dispersal of Ottawa River fish fauna into Gatineau Park (Rubec 1975), which argues against the Rideau Canal dispersal hypothesis. There is little direct evidence for any uniqueness of the populations in Canada. The differing views of origin will only be settled if additional populations are discovered, particularly in areas remote from sport fishing (Coad 1986), or if evidence is found of genetic differentiation in Canadian specimens. Given the restrictions on the use of bait fish in Ontario and Quebec and the elusive character of the species, however, it is doubtful that the species was introduced here and one should tentatively assume that it is an indigenous species.

Protection

No specific protection exists in Canada other than that afforded by the habitat sections of the Fisheries Act. *Noturus insignis* is not a legal bait species in Ontario and the use of bait is illegal in Quebec.

Population Sizes and Trends

Only 49 individuals have been captured in Canada. The majority were collected between 1971 and 1976.

The original locations where Margined Madtom were taken in Quebec were re-sampled in 1982, 1983 and 1984 in an attempt to assess the status of this species. No individuals were captured or observed at these sites, but a single fish was caught upstream in June 1982 [NMC 82-0321], and a second was caught and released from the same location in September 1982. Two specimens were caught in Rivière Lapêche near Saint-Louis-de-Masham on 1 September 1982 [NMC 82-0572] and another on 19 July 1983 [NMC 83-0S35]. Rivière Lapêche drains Lac Lapêche and lies in the same drainage as previous Quebec collections. Extensive sampling in the

area (Gatineau Park) did not reveal any other localities for *Noturus insignis* (Coad 1986).

In Ontario, Coad (1986) reports that attempts to capture the Margined Madtom in the Fall River, Lanark County, in July 1982 were unsuccessful despite exhaustive sampling of riffle areas. This area was originally sampled by OMNR as part of the Stream Inventory Program (qualitative sampling program used to provide base-line assessment of streams in the Province) (G.A. Goodchild, personal communication).

Madtoms are notoriously difficult to capture. According to Taylor (1969), species of *Noturus* are mainly active at night and hide during the day. In fact, one species in the United States was collected and described but could not subsequently be collected from the type locality for many years, despite attempts by a plethora of renowned ichthyologists (B. Coad, Curator, National Museum of Natural Sciences, Ottawa, Ontario; personal communication).

Some species of *Noturus* are quite irregularly distributed and infrequently captured except by intensive survey work. Since Madtoms tend to be secretive, they are most readily collected by chemicals, electrofishing or seining after dusk (Taylor 1969). Madtoms may often be present in quite low numbers. Populations fluctuate wildly and are dependent on spawning success from year to year (Trautman 1981; Bauer et al. 1983), therefore it is difficult to assess their numbers and status. Coad (1986) suggests the initial collecting expeditions may have even contributed to depletion of Margined Madtom populations in Canada. Perhaps they still remain in the two main areas in Canada, but are uncommon and variable in year class success (B. Coad, personal communication).

There is insufficient evidence to evaluate population structure of *Noturus insignis*. Because of its restricted distribution, low population numbers and limited habitat, the continued survival of this species in Canadian waters may be doubtful. It is now either absent from the two known localities or present in numbers reduced below those necessary to ensure capture (Coad 1986).

Habitat

The Margined Madtom inhabits clearwater streams of moderate current. It is usually found in riffles where it lives among rocks, boulders or coarse gravel (Hubbs and Lagler 1967; Taylor 1969; Lee et al. 1980; Smith 1985). Taylor (1969) also states that *Noturus insignis* are recorded from high-gradient streams above the Fall Line.

In Canada, McAllister and Coad (1974) report that the Margined Madtom is a fluviatile species found chiefly in high gradient streams. It lives in clean or normally clear water in moderate to swift current, about riffles, rubble, boulders, or coarse gravel. The first specimens reported from Canada were said to inhabit a situation typical for the species in the United States (Rubec and Coad 1974).

The extremely specific habitat requirements of the Margined Madtom are well documented. It does not appear to be able to exist in even slightly divergent circumstances, despite its evident hardiness.

Exhaustive re-sampling at the first sites of capture in Canada failed to produce additional captures although specimens have been caught upstream as well as in a nearby stream. There has been an increase in Beaver (*Castor canadensis*) activity along the stream creating a series of dams that have submerged the original riffle areas (Coad 1986). Coad (1986) reports that the water flow was slower and silt was found covering the pebbles and cobbles. He suggests that loss or fluctuations in suitable conditions may severely affect the survival of a population limited in numbers. The area may no longer be suitable for the Margined Madtom.

General Biology

Reproductive Capability: There have been no reported studies on the life history of this species in Canada. No observations of spawning activities were recorded in Canada although collections were made during the period of time when they have been observed spawning in north-eastern United States.

Little is known about the spawning of *Noturus insignis* in the United States. The species is nocturnal and probably spawns in relative darkness, under cover (Taylor 1969). Eggs are deposited under rocks near small rapids in a quiet extent of water. They are likely solitary spawners. Males were observed swimming passively near the nests by Fowler (1917). Bowman (1936) observed spawning in late June, while Clugston and Cooper (1960) found that all females collected were spent by 30 July. Almost all were spent by the middle of July, indicating that spawning occurred in late June to early July in Pennsylvania.

Females appear to be mature in their third summer or at age II, some males may attain sexual maturity in their second summer, a year before the females (Clugston and Cooper 1960).

All madtoms lay comparatively few eggs, many species less than 100 at a time (Taylor 1969). Clugston and Cooper (1960) gave an egg count of 107 from a 122 mm female and Fowler (1917) estimated 200 eggs per nest.

Species of *Noturus* are said to be characterized during breeding season by swollen areas on the

head and upper surfaces and by a drab colour (Taylor 1969). Fowler (1917) describes the conspicuous guardian male of *Noturus (Schilbeodes) insignis* as having pale barbels and pale fin edges.

However, Clugston and Cooper (1960) found no reliable external sex characters and determined sex by dissection. During the spawning period, collections had a significant deviation from the 50:50 sex ratio found during other periods but these deviations were not likely due to male mortality. These authors felt that since males guard the nests and young (Fowler 1917; Bowman 1932), they were less readily captured.

Population structure was studied by Clugston and Cooper (1960) in Pennsylvania. They found that most of the fish collected were in age-groups I, II and III with a few in groups 0 and IV. The oldest fish was four years old. They were up to 158 mm in total length (TL) and a specimen 136 mm TL weighed 26.5 g. During the first two years, annual increments of growth averaged 45 mm, while in third and fourth years, increments decreased to about 20 mm. In both sexes, there is a high growth rate during the summer months. After sexual maturity is reached, most of the growth occurs in the warm months after spawning, indicating the majority of food taken by mature fish up to the time of spawning was used for egg/sperm production and after spawning, it was used for growth.

Behaviour/Adaptability: Since the Margined Madtom is a secretive, nocturnal species, it is not readily observed and therefore little is known regarding the effects of human interference. It has been used as a bait fish, particularly in Pennsylvania (Rubec and Coad 1974), and is evidently hardy and able to withstand transport as indicated by documented range extensions.

Reported foods include cladocerans, ostracods, gammarids, midges and debris (Smith 1985). Insects and unidentified fish were found in three individuals by Flemer and Woolcott (1966).

Limiting Factors

Noturus insignis is restricted to moderate to rapidly flowing streams with an abundance of cover. Although wet specimens will survive for several hours in air, oxygen deficient water appears to be a critical factor in controlling distribution. In late summer, madtoms become almost entirely restricted to riffles when oxygen is depleted in pools (Taylor 1969).

Coad (1986) felt that stream alterations resulting from Beaver dams were partly responsible for the depletion of the population in a stream in Gatineau Park. Any barrier, obstruction or activity that reduced riffle areas would undoubtedly have a severe effect on populations of the Margined Madtom.

As mentioned by Coad (1986) and documented by Trautman (1981) and Bauer et al. (1983), populations of species of *Noturus* may fluctuate depending on spawning success. Collection of specimens may also contribute to depletion of populations already low in numbers.

Special Significance of the Species

The presence of *Noturus insignis* in Canada is an interesting anomaly. It is one of the freshwater madtoms which can inflict a painful, but not dangerous, wound from the pectoral spines and associated poison gland (Hubbs and Raney 1944; Scott and Crossman 1973). The species is of no economic importance and its continued existence in Canada is debatable. Its presence here is of considerable interest to an understanding of the glacial history of the area and the species could provide information on the evolutionary processes in madtoms.

Evaluation

The Margined Madtom populations in Ontario and Quebec are found over 130 km north of the United States records. There are two possible explanations for the occurrence of this species in Canada: (1) Margined Madtoms may have been introduced to Canadian waters by the accidental deposition of baitfish and have managed to survive in restricted areas in very low numbers; or (2) Margined Madtoms have been continuously present since post-glacial dispersal, surviving in isolated populations in the eastern part of the Great Lakes watershed (Crossman and VanMeter 1979).

Given the restrictions on the use of bait fish in Ontario and Quebec and the glacial history of the area, the latter hypothesis is more plausible. Since it survives in low numbers and in restricted areas; is at the fringe of its natural range and thus is in jeopardy in Canada, it should be classified as threatened.

Acknowledgments

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D. E. McAllister gave permission to use the drawing of *Noturus insignis* from the book *Fishes of Canada's National Capital Region.*

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Addendum

Since this report was completed, two additional specimens of *Noturus insignis* have been collected from Lake Joseph, Muskoka District, Ontario, by OMNR in 1988 and 1989 (ROM 55829; 58161).

Status of the Brook Silverside, *Labidesthes sicculus*, in Canada*

CHERYL D. GOODCHILD

2168 Harcourt Crescent, Mississauga, Ontario L4Y 1W1

Goodchild, Cheryl D. 1990. Status of the Brook Silverside, *Labidesthes sicculus*, in Canada. Canadian Field-Naturalist 104(1): 36–44.

The Brook Silverside, *Labidesthes sicculus*, is not in any COSEWIC category. Confined to a small region in south-central Canada, populations of Brook Silverside are contiguous with those in the United States, but are at the northern limit of the species' range. Although there have been no population studies, collection records do not indicate any evidence of a decline. Populations appear to be relatively stable and could be expanding slightly. Somewhat tolerant of alterations in habitat, it is extremely sensitive to turbidity and interspecific competition. This coupled with its one-year life cycle has the potential of completely decimating populations in a very short time span. Therefore, regular monitoring of this species should be encouraged.

Le crayon d'argent, *Labidesthes sicculus*, ne figure dans aucune catégorie du CSEMDC. Confinée dans une aire restrainte du centre sud du Canada, cette espèce dont les populations sont voisines de celles des États-Unis, occupe la limite septentrionale de son territoire. Bien qu'aucune étude démographique n'ait encore été effectuée, les données sur les prises en révèlent aucun signe de régression. Les populations semblent assez stables et pourraient même être légèrement en expansion. Malgré sa tolérance relative aux transformations de son habitat, le crayon d'argent est extrêmement vulnérable à la turbidité et à la compétition interspécifique, ce qui, outre sa durée de vie d'un an, pourrait conduire à la disparition de populations entières en un laps de temps très court. En conséquence, il faut encourager la surveillance régulière de cette espèce.

Key Words: Brook Silverside, *Labidesthes sicculus*, crayon d'argent, Atherinidae, silversides, freshwater fishes, status, Canada.

The Brook Silverside, *Labidesthes sicculus* (Cope 1865), is the only member of the family Atherinidae that inhabits Canadian freshwaters, although the marine Atlantic Silverside (*Menidia*) is sometimes found in brackish waters (Scott and Crossman 1973; Scott and Scott 1988). This is a large family containing mostly marine fishes, only two species occur in freshwater in North America; the Inland Silverside (*Menidia beryllina*) in the United States only and the Brook Silverside in both Canada and the United States (Cooper 1983).

Labidesthes sicculus (Figure 1) a small, slender, somewhat pellucid fish is described as straw, pale green or olive coloured. The most conspicuous feature is the brilliant silvery lateral band. Since the body is rather transparent, the swim bladder and vertebral column can be seen through the muscle and peritoneum, particularly in small fish (38 to 51 mm) [Scott and Crossman 1973; McAllister and Coad 1974]. Adults average 76 mm (3 in) in total length (TL), but have been reported up to 110 mm (4.4 in) in Pfleiger (1975).

The inconspicuous first dorsal fin may have from three to six (four in Canadian specimens) weak spines. Both dorsal fins are positioned over the extremely large sickle shaped anal fin which has one spine and between 23 to 27 rays. The top of the head is flattened and the snout is long and pointed. The upper jaw is quite protrusible and is projected into a short beak while the mouth is relatively large. Brook Silversides do not develop breeding tubercles nor do they have special breeding colours (Scott and Crossman 1973; Cooper 1983; Smith 1985).

Distribution

North America: Widely distributed throughout the freshwaters of central North America, the Brook Silverside is found in the Great Lakes, Mississippi, and Gulf Coast drainages (Cooper 1983). On the Atlantic coast, it ranges north from Florida to South Carolina (Smith 1985). At one time two forms were recognized, one thought to occur in the lower Mississippi Valley, Gulf Coast and Atlantic Coast part of the range, and the other from the northern Mississippi Valley and Great Lakes part of the range (Hubbs and Lagler 1967; Lee 1980). However, Bailey et al. (1954) recommended they not be recognized as subspecies. Also, a recent study provides the first published karyotypes for North American atherinids. The subspecies of *Labidesthes sicculus* were examined for chromosomal differences but none were noted (Korth and Fitzsimmons 1987).

*Received and accepted by COSEWIC 11 April 1989 — no designation required.

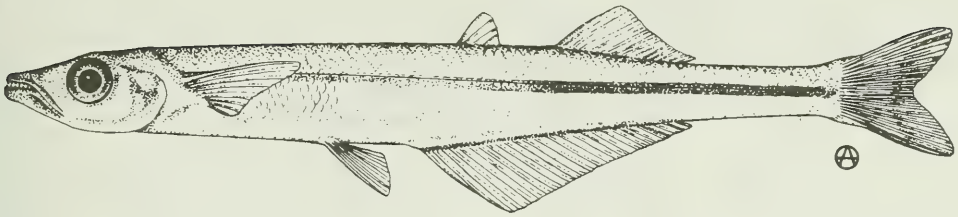

FIGURE 1. Drawing of the Brook Silverside, *Labidesthes sicculus* (drawing by A. Odum; from Scott and Crossman (1973) by permission).

In the United States, the Brook Silverside is found in the Allegheny River system of New York state, west to the lower peninsula of Michigan through Wisconsin and Minnesota, south to the Gulf states of Texas and Oklahoma, along the Gulf coast to peninsular Florida, and north on the Atlantic coast as far as South Carolina (Figure 2) [Scott and Crossman 1973; Lee 1980; Smith 1985].

It was first reported from the Lake Superior drainage in 1975 when it was collected in the Dead River near Marquette, Michigan, both at the mouth and 100 m upstream (Berg et al. 1975). However, Cahn (1927) had placed it in the headwaters of the Upper Fox River and Shawano Lake, Lake Michigan watershed and also in Chain-O-Lakes, northwestern Washburn County, Mississippi River watershed, all in Wisconsin.

Lack of prior records in the Lake Superior drainage suggest that it is indigenous, but very rare, or that it has recently appeared, perhaps by introduction or by migration through the locks at Sault Ste. Marie (Berg et al. 1975). Several new species have appeared in the Lake Superior drainage in the last 10 years due to ballast water introductions (G. A. Goodchild, Fisheries Branch, Ontario Ministry of Natural Resources, Toronto, Ontario; personal communication).

There are few reported range extensions for this species and generally it seems to be declining in the United States. Before 1900, in Ohio, Brook Silverside were common in large streams such as the Maumee, Scioto, and possibly the Ohio River, but today are almost absent in these now turbid waters (Trautman 1981). They were formerly present in the Youghiogheny River, in southwestern Pennsylvania, but are now limited to northwest parts of the state (Cooper 1983). In New York State, it was believed to be a canal immigrant to the Mowhawk River but records from the 1920s to 1930s have not been duplicated in recent years (Smith 1985). Although evidently disappearing in some states, the Brook Silverside is still common in the Lake Erie drainage, western Allegheny drainage and the Finger Lakes. It is particularly common in the old Erie Canal of New York State.

Canada: The Brook Silverside is found in the drainages of the upper St. Lawrence River, the lower Ottawa River, in the drainage basins of lakes Ontario, Erie, St. Clair, and Georgian Bay (Scott and Crossman 1973).

The distribution of Brook Silverside in Canada (Figure 3) has changed little since first documented by Radforth (1944). It has probably expanded in the northern part of its range. The species is most likely indigenous and probably arrived in southern Ontario (Figure 4) and Quebec via a number of postglacial dispersal routes. The Mohawk-Hudson, Fort Wayne and possibly the Champlain and Chicago outlets were suggested by Radforth (1944) to have been routes used to enter Ontario. Brook Silverside probably used the Chicago and Grand Valley outlet (Mandrak 1990) to disperse into lakes Huron and Erie. Dispersal into Lake Ontario may have occurred prior to the formation of Niagara Falls (approximately 12 500 B.P.), and dispersal into Georgian Bay probably occurred during the late glacial Lake Algonquin stage, providing access across the Bruce Peninsula (N. E. Mandrak, personal communication). They presumably survived glaciation in the Mississippi Valley refugium, showing a clear affinity for the Mississippi Valley fauna (Schmidt 1986).

McAllister and Coad (1974) reported that the northern limit of the range of *Labidesthes sicculus* was reached in the National Capital Region (Rideau River). Subsequent surveys have collected specimens from the Ottawa River as far as Kettle Island Bay, south of Gatineau Park [Canadian Museum of Nature (NMC 79-1224, NMC 85-0608]. The most northerly collection of the Brook Silverside appears to be from Wilson Lake near Pointe au Baril Station, northwest of Parry Sound [Royal Ontario Museum (ROM) 30654]. Wilson Lake drains into Georgian Bay via Six Mile Lake and the Naiscoot River. This is an extension of the previously known range.

In Georgian Bay it has been collected from Big Sound, Parry Sound, by the Ontario Ministry of Natural Resources (OMNR) in 1979. Bensley (1915) had found it to be common around the

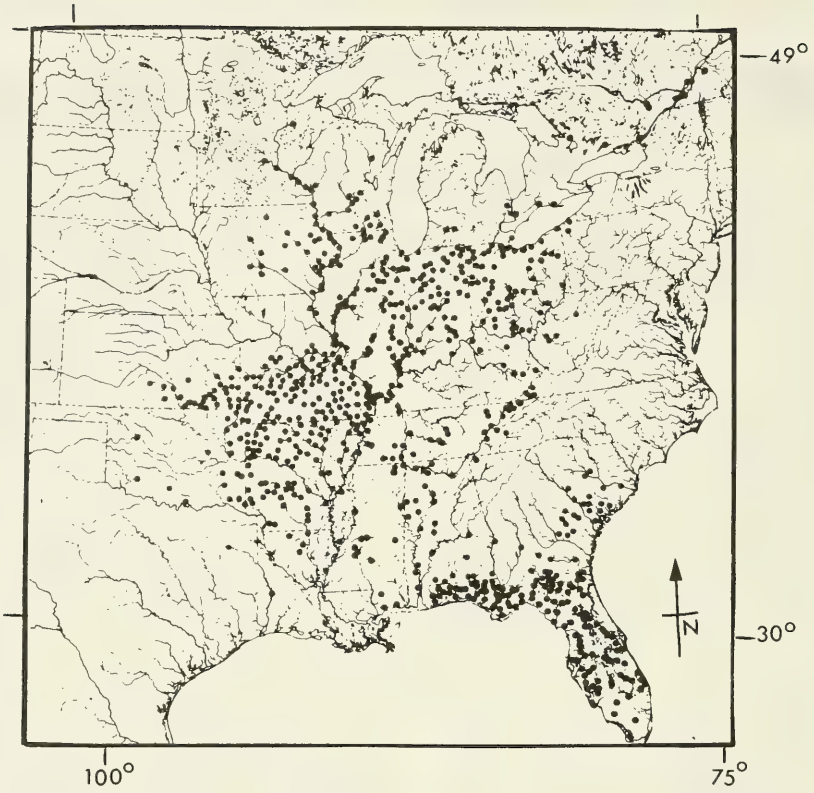

FIGURE 2. North American distribution of the Brook Silverside, *Labidesthes sicculus* (adapted from Lee 1980).

shore in Georgian Bay and in tributaries such as the Go Home River. Recent collections from Woods Bay, Victoria Harbour, Matchedash Bay and Honey Harbour indicate the Brook Silverside is still quite common in southern Georgian Bay (OMNR and ROM records).

Although presence in Lake Huron, proper, has not been mentioned in the literature it is not surprising that it has been found there due to its occurrence in both the St. Clair River and Georgian Bay. In 1986, specimens were taken inside the breakwall in Sarnia Bay of Lake Huron by OMNR collectors. It has also been collected in the Bayfield River, south of Goderich, Ontario, a tributary to Lake Huron [ROM 43028]. It is frequently found in many tributaries of Lake Huron (Ausable, Maitland, and Saugeen rivers), Lake Erie (Grand and North rivers), and Lake St. Clair (Sydenham and Thames rivers) [NMNS; OMNR; ROM].

In his studies of the fishes of eastern Ontario, Toner (1943) found it was common in both Lake Ontario and the St. Lawrence River but recorded it from only one inland lake (Grippen Lake, of central Leeds County). Elsewhere in Leeds County, he considered it was either rare or absent. In contrast, Scott (1967) considered Brook Silverside to be very abundant in some inland lakes in Leeds County, particularly in summer. It has since been collected in Grippen Lake in the early 1970s as well as several other lakes in the area: Mud Lake, Mosquito Lake, Opinicon Lake, and Whitefish Lake (OMNR and ROM records).

Protection

General protection is afforded by habitat sections of the Fisheries Act, but there is no specific protection for the species in Canada. Since it is not classed as a baitfish in Ontario, it cannot be sold as such so this would provide some protection.

In the USA, it was listed as rare in Maryland and Pennsylvania (Miller 1972). It is not included in the American Fisheries Society's *Protected Fish of the United States and Canada* (Johnson 1987).

Population Sizes and Trends

Labidesthes sicculus is a common forage fish in lakes and streams of eastern North America. Cahn (1927) described it as being one of the most abundant and typical species in Waukesha

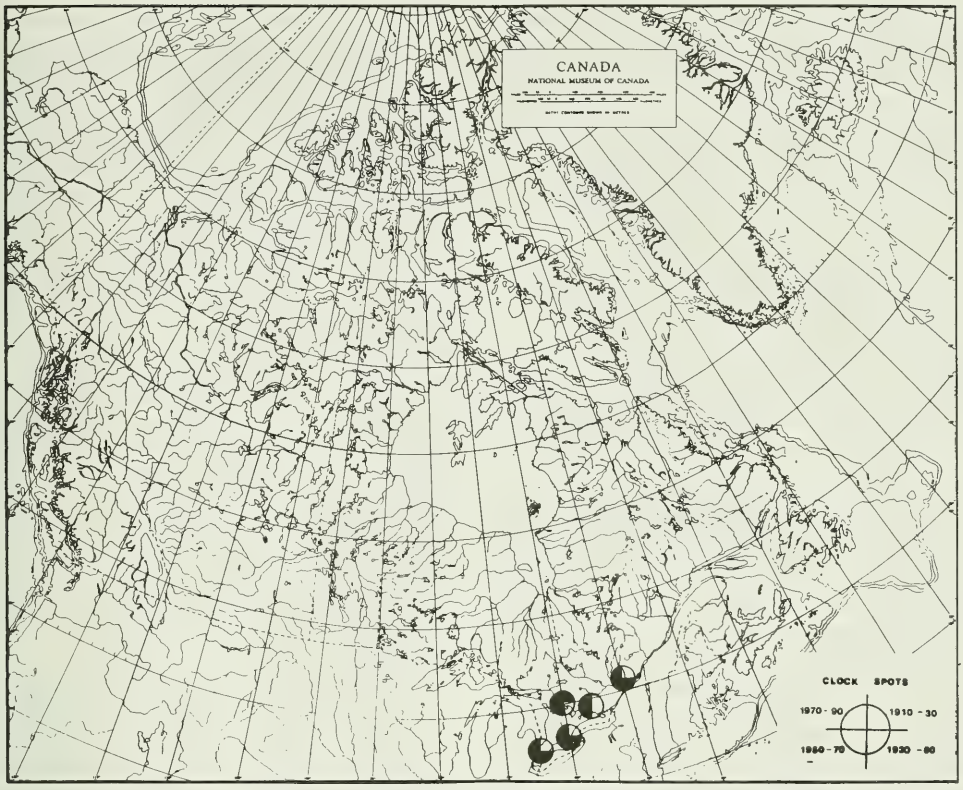

FIGURE 3. Distribution of Brook Silverside, *Labidesthes sicculus*, in Canada.

County, Wisconsin and considered it to be very abundant throughout much of its range in the United States. Brook Silverside were usually the most abundant species in seine hauls of Crooked Lake, Indiana (Nelson 1968).

There are few reported range extensions for this species and populations generally seem to be declining. In Illinois, it is somewhat decimated due to excessive siltation (Smith 1979). Cooper (1983) describes it as being more common in lakes than in streams in Pennsylvania and although formerly present in the Youghiogheny River, it is now extremely limited to the northwestern parts of the state.

Trautman (1981) discusses extensively the decline in Brook Silverside in Ohio. Before 1900, it was usually found to be abundant in most areas investigated. In surveys undertaken in the 1930s to 1950s, it was far less abundant, taken in less than a tenth of the collections made. Since the 1940s, Brook Silverside have been found primarily in small clear upland brooks or in recently constructed reservoirs.

In contrast to the general trend of decreasing populations, *Labidesthes sicculus* seems to readily invade reservoirs and impoundments, quickly becoming abundant, particularly in those with clear water and sandy/gravel bottoms (Cross 1967; Smith 1979). In Missouri and Iowa, it is the most abundant small fish in large reservoirs (Harlan and Speaker 1956; Pflieger 1975).

It appears that populations of Brook Silverside in impoundments may be extremely unstable and subject to collapse in a very short time. McComas and Drenner (1982) published the results of a study to determine the cause of sudden decrease in *Labidesthes sicculus* population in impoundments. They found that populations are completely replaced when in competition with *Menidia beryllina*, the Inland Silverside.

In Canada, few observations indicate that the Brook Silverside attains an abundance comparable to that in lakes of the northern United States (Scott and Crossman 1973). For example, in Indiana at least 11 500 specimens were used in a study by Nelson (1968). In Grippen Lake, Leeds County, eastern Ontario, Toner (1943) noted that immense numbers could be seined at night on sandy beaches. He also observed large numbers in Lake Ontario, from a dock in Kingston. Bensley

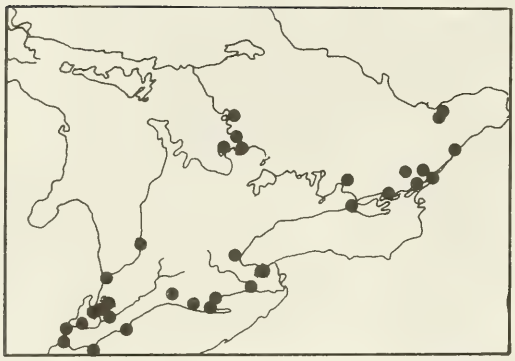

FIGURE 4. Distribution of Brook Silverside, *Labidesthes sicculus*, in Ontario (adapted from Radforth 1944).

(1915) reported that he observed enormous numbers of young Brook Silverside in schools offshore but commonly only collected a few specimens in seine hauls.

In a study comparing growth of nine co-occurring fish species in Lake Opinicon, Ontario, at least as many specimens of Brook Silverside were captured and analyzed as other species but there is no indication whether that is indicative of the population numbers present in the lake (Keast and Eadie 1984).

Numbers of specimens, collected in various locations throughout Ontario since the early 1970s range from one to over 100, but are not indicative of exceptionally large populations. Since no population studies have been done on this species in Canada, little can be deduced regarding present population trends.

Habitat

The Brook Silverside is a surface-dwelling fish with a strong schooling tendency (Smith 1979). Preference for near surface water is characteristic of the species. The most outstanding feature of environmental preference is the remarkable difference in habitat selection displayed by juveniles and adults. Young Brook Silverside are one of the few freshwater fishes to adopt a pelagic surface habitat in large lakes soon after hatching (Cooper 1983). Hubbs (1921) first reported this phenomenon and he found the tendency more pronounced in lakes than in streams. Young Brook Silverside prefer to occupy the top few centimeters over deep water. In contrast, the adults show an exclusive selection of shallow water over shoals. Young fish move to a permanently shallow water habitat after attaining approximately two thirds of adult size (Cahn 1927). This occurs during August and September in Michigan and during winter the entire population can be found close to the shore beneath the ice (Hubbs 1921 *after* Evermann and Clark 1920).

Brook Silverside are reported from widely variable habitats summarized by Lee (1980: 557) as follows: "abundant near surface of clear, vegetated and unvegetated warm waters of streams, lakes and reservoirs". In New York State it is reported to be most abundant in weedy areas of streams and lakes (Smith 1985). Although generally preferring areas with no noticeable current, it is occasionally taken from flowing water (Harlan and Speaker 1956). Tolerance of fairly rapid flow is also aptly demonstrated by collections from streams having considerable current, such as near the falls in the Go Home River (Bensley 1915).

Although reasonably adaptable, the species is decidely intolerant of turbidity and is invariably absent from turbid waters. Trautman (1981) suggests it has moved into the small clear upland brooks or into cleaner backwaters of recently constructed reservoirs to avoid the turbid conditions now found in the large streams in Ohio, which it occupied prior to 1940. Brook Silverside also stop feeding when water becomes temporarily turbid (Trautman 1981; Smith 1985). However, specimens are often taken from turbid water in the Barge Canal System, New York State.

Discrepancies to the reported substrate preference by Brook Silverside may be explained by choice of selectively different spawning habitat. Shallow water with an absence of vegetation but having sandy, gravelly, or rocky bottom is said to be characteristic habitat of the species by many authors (Toner 1943; Cross 1967; Trautman 1981). Yet, preference for localities with aquatic vegetation is described by others (Bensley 1915; Smith 1985). Possibly the species selects weedy areas only during spawning and hence those who reported a selection for aquatic vegetation had observed the species during the spawning period only. Spawning in spring among aquatic vegetation is reported by Scott (1967). Rooted aquatic vegetation was abundant in the section of the river where Berg et al. (1975) located Brook Silverside. Their collections were made in June and the specimens they kept were gravid females indicating that spawning was imminent.

Although the distribution of Brook Silverside in Canada is limited, there is little evidence to suggest the species has declined appreciably since the early 1900s when collections were first made. There have been no specific studies to determine the extent of *Labidesthes sicculus* populations in Canada and all the inherent difficulties associated with making estimates based on sporadic, unspecific sampling preclude determining critical habitat trends.

General Biology

Reproductive Capability: Labidesthes sicculus spawns at the age of one year. Although Fogle

(1959) noted a few males in Arkansas with two annuli, the oldest individuals collected in Crooked Lake, Indiana were estimated to be between 21 and 23 months old and thus all spawning adults were one year of age (Nelson 1968). Hubbs (1921) found only one annulus evident on scales of breeding fishes taken in southeastern Michigan. Cahn (1927) examined 478 adults and never found more than one annulus. He concluded that Brook Silverside die before their second winter, probably at about 17 months of age.

Spawning occurs in spring and early summer in and around aquatic vegetation. It can also occur over gravel in a moderate current and time of spawning may be temperature dependent. Due to incomplete data available in the literature, it is difficult to compare temperature/time of spawning at different locations. Cahn (1927) reported that pairing began when water temperature reached 18°C, actual spawning commenced at 20°C and optimum spawning occurred at 23°C but he did not report exact dates. The breeding activities of Brook Silverside during May and June of a reportedly cool season in Michigan began after surface water temperature had risen above 20°C. Also, there was a temporary cessation of spawning when water temperature dropped below 20°C (Hubbs 1921). Indiana Brook Silverside spawn from the middle of June until early August but water temperatures are not reported (Nelson 1968). Spawning in Missouri commences as early as 22 May but temperatures are also unavailable (Pflieger 1975). *Labidesthes sicculus* is identified as a protracted spawner in Lake Opinicon, Ontario with a duration of 41 days (11 June to 22 July) [Keast and Eadie 1984].

Little information is available on breeding frequency. Nelson (1968) observed fully ripe females containing mature orangish eggs up to 1.2 mm but also noted were many immature whitish eggs up to 0.6 mm. This may indicate that females spawn more than once or merely that eggs may not all mature at once. Examination of 26 females captured immediately after spawning found all but three with ovaries completely empty and these contained only half a dozen eggs each (Cahn 1927). Males on completion of a spawning act were seen pursuing other females. Possibly, males spawn repeatedly while females spawn only once. Males established ill-defined territories. Several males may chase a female moving into the area. Spawning occurs when one male and one female pair but no nest building or guarding occurs (Hubbs 1921; Cahn 1927; Nelson 1968)

After extrusion, the egg settles slowly to the bottom. Each egg has at least one long adhesive filament which functions as an anchoring device for the non-adhesive egg. The number of filaments attached to Brook Silverside eggs may show a geographical gradation. Eggs from the Peace River, Florida, had two or three attachment filaments (Rasmussen 1980); eggs from Lake Fort Smith, Arkansas, had two filaments per egg (Fogle 1959); while eggs from Portage Lake, Michigan (Hubbs 1921), Oconomowoc Lake, Wisconsin (Cahn 1927), and Crooked Lake, Indiana (Nelson 1968), had only one filament.

Scott and Crossman (1973) reported egg diameters of 0.8 to 1.2 mm but Rasmussen (1980) found egg diameters ranged from 1.1 to 1.4 mm. Mature eggs are orange in colour and contain numerous oil globules within the yolk. Eggs develop rapidly hatching in eight days in 25°C water and within eight to nine days in lake waters of 23°C (Cahn 1927). Rasmussen (1980) described the larvae and juveniles in considerable detail and notes geographical differences.

No data are available on fecundity. In a study of Brook Silverside in Crooked Lake, Indiana, spawned eggs were considered to be numerous. However, year class strength may fluctuate considerably as evidenced by the much lower abundance observed during the second year of the two-year study (Nelson 1968).

Growth of young Brook Silverside is rapid. Hubbs (1921) estimated an initial average growth of approximately a millimetre per day slowing to 0.40 mm per day, attaining an estimated 70 to 80% of adult size by three to four months of age. Nelson (1968) noted that in an Indiana lake population, some fish reached the modal size of a 12-month-old spawning group in only three months. Rapid growth in the first months of life is critical to survival and attainment of sexual maturity in temperate freshwater fishes. Size-distribution histograms for nine species of fish in Lake Opinicon, Ontario, show that Brook Silverside were lighter per unit length than other species investigated, reflecting its long and narrow body shape (Keast and Eadie 1984).

Species Movement: Long distance migration has not been observed for Brook Silverside. There is some evidence that the species may travel for some distance as it readily invades new impoundments. Also, when river habitats become too turbid they readily move into clearer upstream areas. Large schools of Brook Silverside are frequently observed as well, particularly in lakes (Bensley 1915; Hubbs 1921).

Labidesthes sicculus have a definite daily cycle of activity that seems to be regulated primarily by light intensity. Extremely active in the day, they usually become quiescent at night (Trautman 1921). Being positively phototrophic, they are active on moonlit nights and night activity can be induced by shining a spot light on the water.

Nighttime sampling may yield many more specimens than daytime collections (Cahn 1927). The use of artificial lights for fishing is not allowed in Ontario.

Pelagic habitat selection by juveniles has already been discussed. There is also an interesting nocturnal-diurnal pattern of migration exhibited by young Brook Silverside. Prior to permanently adopting an inshore habitat in late August and September, young Brook Silverside migrate into littoral areas each night and return to the surface layer over deep water during the day. Cahn (1927) found that the inshore movement was coincident with a drop in temperature of the surface water over the depths as well as a change in the pH of the water at that stratum. By the end of the summer, all of the Brook Silverside become established inshore where they remain all winter.

Behaviour/Adaptability: The Brook Silverside is a predacious fish that feeds on zooplankton and small insects (aquatic and terrestrial). It feeds in a snapping fashion with its beaklike toothed jaws and may frequently leap out of the water to catch flying insects (Scott and Crossman 1973; McAllister and Coad 1974). The diet of this highly specialized feeder is made up of Cladocera (frequently up to 80% by volume), small flying insects (up to 40%) and *Chaoborus* larvae (50%) [Keast and Webb 1966]. Occasionally other items may be utilized; Boesel (1938) reported finding a spider and small fish in the stomach contents of Brook Silverside examined.

There is differential food selection between juveniles and adults. Boesel (1938) summarized the food items of two size ranges of Brook Silverside. Smaller individuals (average 35.9 mm) had a diet composed almost entirely of Entomostraca (mainly copepods), whereas larger individuals (average 61.2 mm) fed predominantly on insects, particularly adult midges. He found there was a gradation of feeding habits accompanying increasing size. The shift in diet from microcrustaceans to insects is concurrent with the migration of larger juveniles to a shallow water habitat (Pflieger 1975).

Parasites of Brook Silverside from Lake Erie have been recorded by Bangham and Hunter (1939) who noted that specimens from eastern Lake Erie were relatively unaffected although those from the west end of the lake harboured cestodes, trematodes, and nematodes. This was based on the examination of 30 species of which 10 were infected with seven different species of parasites. In a latter study, Bangham (1972) resurveyed the parasites of Lake Erie and found four infected Brook Silverside out of the nine that were examined. All of these harboured species of trematodes. Hoffman (1967) lists five species of trematodes and one species of nematode for Brook Silverside.

Labidesthes sicculus appears to be relatively tolerant of human disturbance readily invading newly created reservoirs and expanding into new areas when unfavourable habitat alterations occur in formerly occupied areas. It survives in areas where there has been considerable alteration of habitat through agriculture and construction as has occurred in southern Ontario.

Limiting Factors

Labidesthes sicculus is particularly susceptible to increased turbidity, a condition which has become more widespread in southern Ontario as a result of urbanization, construction and agricultural activities (Scott and Crossman 1973). It disappears from waters that become turbid perhaps as a result of an inability to feed. Both Trautman (1981) and Smith (1985) report that activity and feeding cease when surface water becomes turbid. It has been suggested that cessation of feeding in turbid waters is triggered by the same mechanism (light intensity) that controls nocturnal inactivity. Brook Silverside are believed to feed actively mainly during daytime and rest during nighttime. However, Keast and Webb (1966) observed both nocturnal and diurnal feeding.

Brook Silverside grow at an extremely rapid rate during their first few months of life. Therefore, any stress which might impede their ability to obtain sufficient food would have debilitating effects on the population. To determine the causes for rapid dwindling and extinction of populations of *Labidesthes sicculus* in a reservoir, a study of feeding mechanics was initiated by McComas and Drenner (1982). They found that when in direct competition for zooplankton with another atherinid (*Menidia beryllina*), Brook Silverside experienced 75 to 86% mortality in laboratory studies. The two species have different feeding rates for copepods and in turbid water, feeding rates of *Menidia* were significantly higher, which is possibly another explanation for the strongly detrimental effect of turbid waters on Brook Silverside populations.

Undoubtedly, Brook Silverside are extremely susceptible to catastrophic events due to their one year life cycle. If for example, an entire year class was decimated, then the complete population in that area could be destroyed. Brook Silverside may be restricted by severe winters and ice build-up due to preference for an inshore habitat after the first few months of life. An entire population could therefore be eliminated by extremes in water temperature during winter. In a laboratory study to determine if there was a size differential in

mortality due to lethal temperature, most deaths began when the temperature of the water dropped below 7°C. No differential mortality with respect to size was observed, however (Nelson 1968).

Predation by other species may be a limiting factor for Brook Silverside because they are common forage for many species. Avoidance of shallow water by juveniles may protect the population from excessive predation. As they are for the most part the only inhabitants of these waters, they escape the competition existing in shallow water. Small size would make them ideal food for the dozens of species which feed in the shallows along the shore. In studies of bass populations in the southern United States, Timmons et al. (1980) reported that small Largemouth Bass (*Micropterus salmoides*) selected Brook Silverside in May but later avoided them and Largemouth Bass larger than 100 mm consumed none.

Special Significance of the Species

The Brook Silverside is the only member of the family Atherinidae that lives in Canadian freshwaters. Atherinids compose a family whose members are typically salt water forms, none of which attains a large size.

Although widely distributed throughout the freshwaters of central North America, *Labidesthes sicculus* is confined to a small region in south-central Canada. It is undoubtedly of very minor importance in Canadian waters because of its low numbers and limited distribution (Scott and Crossman 1973). It is, however, an ideal forage fish and may be an important prey for game fishes when abundant. In the United States, larger specimens are occasionaly used for bait by sports fishermen but they are very sensitive to low oxygen and die very quickly in a bait bucket (Cooper 1983). They are not legal baitfish species in Ontario.

There is little public interest in the Brook Silverside and these tiny fishes are often overlooked or considered to be just another minnow. They are exceptional in their surface feeding mechanics, in the pelagic habitat requirements of juveniles and in their one-year life cycle.

Evaluation

The Brook Silverside is an ideal forage fish and when abundant, may be an important prey species. The status of Canadian populations is not fully understood. Collection records do not indicate any decline in Brook Silverside populations and perhaps its range is expanding slightly. Although it is not apparently in any immediate jeopardy, populations can be totally eliminated in an extremely short time span because of its one year life cycle. Excessive turbidity and interspecific competition are apparently primarily responsible for the decline of Brook Silverside in areas of the United States.

The Brook Silverside is indigenous to Canada and at the fringe of its range here. However, Canadian populations are contiguous with those in the United States and the species appears to be reasonably abundant and not particularly vulnerable at this time. For these reasons classification by COSEWIC is not necessary at this time, however its status should be re-examined at regular intervals.

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Status of the Banded Killifish, *Fundulus diaphanus*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of the Banded Killifish, *Fundulus diaphanus*, in Canada. Canadian Field-Naturalist 104(1): 45–52.

The Banded Killifish, *Fundulus diaphanus*, is one of three species of the genus occurring in Canadian waters and is a species preferring the quiet waters of lakes and ponds. It tolerates temperatures in excess of 30°C, but prefers temperatures in the range of 21° to 28°C. They are often used by anglers as bait fish and can survive in water with low oxygen content for extended periods of time. In Canada, the Banded Killifish is widely distributed in the Maritime Provinces but is known from only a few localities in Newfoundland. The range extends west through southern Quebec and Ontario in the Great Lakes watershed to Lake Huron. They have been recorded from the Red River at Winnipeg, Manitoba, Crowduck Lake, Manitoba and Lake of the Woods, Ontario. The species has an extremely limited distribution in Newfoundland and Manitoba where further immigration in these areas is unlikely due to lack of suitable habitat or barriers to dispersion.

Le fondule barré, *Fundulus diaphanus*, l'une des trois espèces du genre *Fundulus* que l'on trouve au Canada, préfère les eaux calmes des lacs et des étangs. Ce poisson très robuste tolère des températures dépassant 30°C bien qu'il soit plus à l'aise dans des eaux où la température se situe entre 21° et 28°C. Les pêcheurs à la ligne l'utilisent souvent comme appât, et il est capable de survivre dans une eau très pauvre en oxygène pendant une période prolongée. Au Canada, le fondule barré est largement répandu dans les Maritimes, sauf à Terre-Neuve où il n'a été observé qu'à quelques endroits seulement. Son aire de répartition s'étend vers l'ouest dans le sud du Québec et de l'Ontario, et le bassin des grands Lacs jusqu'au lac Huron. On a signalé sa présence à deux endroits au Manitoba, soit dans la rivière Rouge à Winnipeg et le lac Crowduck, ainsi que dans le lac des bois en Ontario. Le fondule barré a une répartition extrêmement limité à Terre-Neuve et au Manitoba où l'implantation de l'espèce paraît improbable à cause de barrières qui empêchent sa dispersion ou de l'absence d'habitats appropriés.

Key Words: Banded Killifish, *Fundulus diaphanus*, fondule barré, Fundulidae, killifishes, topminnow, rare and endangered fishes, status, Canada.

The Banded Killifish, *Fundulus diaphanus* (Lesueur 1817), is a member of the killifish or topminnow family (Fundulidae). These are small fishes with a wide distribution in the fresh and salt waters of North and Central America. They occur also in Europe, Africa, Asia and the East Indies; they are most common in the southeast United States (Scott and Crossman 1973). The genus *Fundulus*, of the 45 nominal genera, is represented in Canada by three species: *Fundulus diaphanus, Fundulus heteroclitus,* and *Fundulus notatus.* These fishes are often referred to as topminnows because of their habit of surface feeding (Leim and Scott 1966; Scott and Crossman 1973).

Banded Killifish (Figure 1) average 6 to 8 cm in total length (TL), with a maximum known size of 11.4 cm (Scott and Crossman 1973). Like most topminnows, the mouth is small and directed upwards. The lower jaw protrudes beyond the upper when the mouth is closed. These fish have an overall brown to olive-green colouration dorsally, shading to white or yellow below. There are many (12 to 20) dark, vertical bars on the sides, more widely spaced in females, and these may be accentuated during spawning. The vertical bars and overall colouration are more intense during spawning and the dorsal fin may show a greenish or golden wash as well as the hint of a dark band or two (Scott and Crossman 1973).

The Blackstripe Topminnow (*Fundulus notatus*) is known in Canada only from the Sydenham River system in southwestern Ontario (*see* McAllister 1987), whereas the Mummichog (*Fundulus heteroclitus*) is restricted to the brackish shore waters of the Atlantic provinces, including southwestern Newfoundland, and to the estuaries and salt marshes of the Gulf of St. Lawrence to the head of the tide above Anticosti Island (Scott and Crossman 1973). The Banded Killifish is widely distributed in the Maritime Provinces, Quebec, and Ontario; its limited distribution in Manitoba and Newfoundland begs an examination of its status in Canada. This report documents the current status of the species in Canada for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

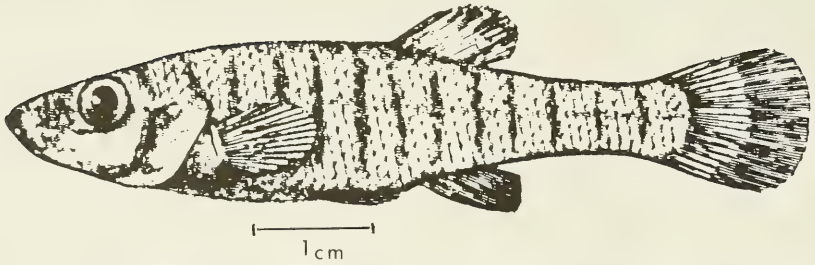

FIGURE 1. Drawing of the Banded Killifish, *Fundulus diaphanus* [adapted from Scott and Crossman (1973) by permission].

Distribution

Banded Killifish occur along the eastern seaboard from South Carolina north to the Maritimes and west through southern Canada (Figure 2) to the Red River of Manitoba and the Yellowstone River of eastern Montana in the United States (Scott and Crossman 1973; Gilbert and Shute 1980).

In Canada, the species is widely distributed (Figures 2,3) in the Atlantic Provinces, with the exception of Newfoundland where it is known only from a few localities in the southwest and from the Burin Peninsula (Scott and Crossman 1973; Gibson et al. 1984). The Canadian distribution continues west through Quebec in the St. Lawrence valley where suitable habitat may be found and on into the Great Lakes watershed of southern Ontario. The species is not known from Lake Superior (Scott and Crossman 1973), but has been recorded from Lake of the Woods (Stewart et al. 1985). In Manitoba, the species has only been recorded from the Red River at Winnipeg and Crowduck Lake (Winnipeg River Watershed), near the Ontario border (Stewart et al. 1985).

Protection

No specific protection for the species exists in Canada. General protection is available through the habitat sections of the Fisheries Act. The species is considered to be of special concern in the Province of Manitoba (Johnson 1987). In Ontario, the species is not classed as a bait fish and it is illegal to use it as such.

In the United States, Banded Killifish are considered to be endangered in Pennsylvania and South Dakota (Miller 1972), and disappearing from Illinois (Smith 1979). The species has protected status in the states of Ohio and South Dakota due to its rarity (Johnson 1987).

Population Sizes and Trends

As for most small fishes, such as the minnows, no population estimates have been made for the topminnows. In many parts of the range there is no direct evidence for trends in population size.

The species is locally abundant in parts of its United States range, but has undergone a decline since the 1920s (Trautman 1957). This decline is particularly evident in the western sectors of the distribution where the species remains in a few lakes of glacial origin in Illinois (Smith 1979) and has disappeared from many localities in Ohio (Trautman 1957) and is considered to be endangered in Pennsylvania and South Dakota (Miller 1972; Johnson 1987).

Within the known Canadian range (Figure 3), Banded Killifish appear in moderate abundance and collection records indicate that the range may be stable [National Museum of Natural Sciences

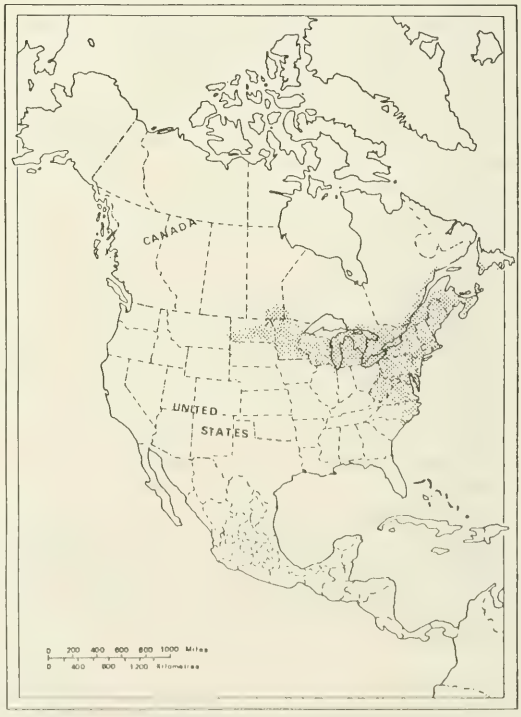

FIGURE 2. Approximate North American range of the Banded Killifish, *Fundulus diaphanus*.

FIGURE 3. General distribution of Canadian collection records of the Banded Killifish, *Fundulus diaphanus*. Closed circles represent collections made prior to 1980, triangles represent post 1980 collections. (Based on sources referenced in the text. Some collections have been omitted due to map scale).

(NMC), now Canadian Museum of Nature; Royal Ontario Museum (ROM); Ontario Ministry of Natural Resources (OMNR) records]. The species is particularly abundant in Nova Scotia (Fritz and Garside 1977).

In insular Newfoundland, the species has been recorded from the southwest corner of the island near Stephenville Crossing at the head of St. George's Bay (48°N, 59°W) and in the Highlands River 50 km south of Stephenville (Scott and Crossman 1964; Gibson et al. 1984). In 1983, Banded Killifish were collected from Freshwater Pond on the Burin Peninsula (47°6′N, 55°16′W); this is the most easterly occurrence recorded for the species (Gibson et al. 1984). The species seems to be abundant at these locations and breeding populations appear to exist; however, suitable habitat along the coast is limited, and the steep gradient of the rivers may constitute barriers to immigration to sites further inland (Gibson et al. 1984).

Species records [NMC; ROM; OMNR] are sparse along the North Shore of the Gulf of St. Lawrence and the St. Lawrence River to Quebec. The most northerly distribution reported for the species is at the Matamek River (50°18′N, 65°57′W) on the North Shore (Gibson and Sears 1977) where the fish were relatively abundant. Such occurrences should be expected due to the proximity of other collections. However, as in insular Newfoundland, this coast is rocky and suitable habitat is probably limited.

In Ontario and Quebec, the distribution and abundance would appear to be relatively stable as recent collection records confirm the presence of the species in the same watersheds where collected

earlier in the century (e.g. Mongeau et al. 1972; McAllister and Coad 1974; NMC, OMNR, and ROM records). With the exception of recent collections from Lake of the Woods (*see* Stewart et al. 1985), no range extensions have been reported. The presence of the species in Shoal Lake in the Lake of the Woods region should not be surprising as Stewart et al. (1985) also report recent (1982) evidence for the species in Crowduck Lake, Manitoba (50°05′N, 95°08′W), part of the same Winnipeg River drainage system.

Banded Killifish are known in Manitoba only from one other collection from the Red River at Winnipeg (Stewart-Hay 1954), although the species is known from the Red River drainage in North Dakota and Minnesota (Eddy and Underhill 1974; Owen et al. 1981). Stewart et al. (1985) considered the species to be extremely rare in Manitoba where it has not otherwise been found despite frequent collecting efforts.

Habitat

Scott and Crossman (1973) describe suitable habitat as quiet waters of lakes and ponds with sand, gravel, or detritus-covered bottoms and patches of submerged aquatic vegetation. The species is most abundant in very shallow waters and has a preference for clear, glacial lakes with sluggish waters and abundant vegetation (Trautman 1957; Smith 1979; Cooper 1983). Water clarity is important as the species relies on visual perception in prey selection (Desgagné and Lalancette 1984).

Banded Killifish appear to be tolerant of low dissolved oxygen. Although 0_2 limits have apparently not been determined, these fish have been known to exist for long periods of time in minnow buckets and even out of water (*see* Scott and Crossman 1973). They also have a wide tolerance of water temperatures and have been known to exist at temperatures to 38.3°C (Carlander 1969), although Rombough and Garside (1977) reported an upper incipient limit of 34.5°C. Melisky et al. (1980) indicated that the distribution within a water system may be influenced by temperature and found that fish in Pennsylvania have a preference for waters in the neighborhood of 28.6°C while those in Nova Scotia exhibit a preference of 21.0°C. In Quebec, prespawning activities became apparent at 21°C and spawning probably occurs when water temperature reaches 23°C (Scott and Crossman 1973).

The species is euryhaline, but usually inhabits freshwater streams and lakes, rarely being found in brackish or marine waters (Fritz and Garside 1974b, 1975). In Nova Scotia, they are abundant in certain brackish lakes where their fecundity appears to be higher than in nearby oligotrophic lakes possibly because of the greater productivity in the former (Fitz and Garside 1975). Although the species has an ultimate salinity preference for freshwater, they acclimate easily to salt water (Fritz and Garside 1974a; Garside and Morrison 1977; Weisberg 1986) and can tolerate salinities in excess of 20 ppt (Griffith 1974; Weisberg 1986). Griffith (1974) suggested that the apparent immediate preference for fresh water was acclimation dependent which may explain their presence in Prince Edward Island, Anticosti Island, and Newfoundland.

General Biology

Systematic Notes: Two subspecies of Banded Killifish are recognized and both exist in Canada (Scott and Crossman 1973; Robins et al. 1980). The Eastern Banded Killifish, *Fundulus diaphanus diaphanus*, is found in the Atlantic drainage and the range extends west to the upper St. Lawrence River and eastern Lake Ontario. The Western form, *Fundulus diaphanus menona*, ranges eastward from the Yellowstone River in Montana to Lake Erie. The subspecies integrate along and in Lake Ontario and the upper St. Lawrence River (Scott and Crossman 1973; Gilbert and Shute 1980). Hybridization with other species of the same genera is said to be rare (Scott and Crossman 1973), although Banded Killifish do appear to readily hybridize with Mummichogs where the species are sympatric (Fritz and Garside 1974a).

Life History: Individuals reach maturity at an age of 1+ years and a total length of about 6 cm (Carlander 1969). Adults attain maximum size in three years (Cooper 1983), but information on longevity in the species is lacking. The size of adults varies with location, but usually ranges from 6 to 8 cm. Larger individuals are more common in the Maritime Provinces where individuals up to 11.4 cm in length have been recorded (Scott and Crossman 1973). Fritz and Garside (1975) found that Banded Killifish from brackish lakes grew faster in the first year, attained greater overall size and were more fecund than fish from oligotrophic lakes. They attributed this difference to the greater productivity in the brackish lake, but despite the advantage in brackish waters, the species showed a preference for fresh water and they concluded that salinity for some reason is important in the distribution of the species (Fritz and Garside 1974b, 1975).

Spawning has been described by Richardson (1939) and takes place from April to May depending on water temperature, a temperature of

around 21°C being preferred (Carlander 1969). McAllister and Coad (1974) reported finding females in spawning condition in the Ottawa River watershed in June when water temperature was around 23°C. Males select breeding sites in the quiet shallows of weedy areas. The males defend these territories and develop more intensive colouration while the females remain pale (Scott and Crossman 1973). Males spawn individually with females and there is no nest building or care of the young (Cooper 1983). The males and females seem to pair off according to size and after pursuit by the male, the female extrudes her eggs in clusters of five to 10 eggs. The eggs are attached to the female by a thread and following fertilization, detach and stick to vegetation by individual, adhesive threads. This continues until all eggs of the female are laid (*see* Scott and Crossman 1973).

A female may contain up to 250 or so eggs (Carlander 1969) of about 2 mm in diameter. The eggs hatch in 11 to 12 days at water temperatures of 22 to 27°C (Cooper 1936). The fry are 6 to 7 mm long and larvae 7 to 12 mm have been described by Fish (1932) and Auer (1982). Fritz and Garside (1975) reported on growth rates, length-weight relationships and fecundity between two populations in Nova Scotia and determined that fish from brackish waters did better than their counterparts in fresh water. They attributed this to the higher productivity of the brackish lake. Growth in the first year appears to be rapid. From a 6 to 7 mm fry, young fish may attain lengths of 2.0 to 6.4 cm by the end of the year (Trautman 1957; Smith 1952). The largest specimen on record in Canada measured 11.4 cm total length and was taken in Lake O'Law, Nova Scotia (Scott and Crossman 1973).

Parasites of the species have been listed by Bangham and Hunter (1939) and Hoffman (1967). Banded Killifish serve as a forage species to game fish where the ranges overlap and they occur in numbers. It may also be an important item in the diet of fish-eating birds such as the American Merganser (*Mergus merganser*) or the Belted Kingfisher (*Megaceryle alcyon*) in some areas (White 1943, 1957).

Behaviour: Spawning behaviour is similar to that of other killifishes with males defending territories and spawning individually with females (Cooper 1983) and has been described in detail by Richardson (1939). The species is usually found in schools which tend to favour sand-bottom shallows (Scott and Crossman 1973; Smith 1979). The schooling behaviour may be related to predator avoidance (*see* Godin and Morgan 1985). There is no information on seasonal migrations but the distrtibution of the fish within a body of water is probably related to salinity and temperature preferences and to the availability of suitable prey (Fritz and Garside 1974a; Griffith 1974; Garside and Morrison 1977; Weisberg 1986).

Food and Feeding: Banded Killifish are versatile feeders and despite the superior position of the mouth, they utilize all levels of the water column (Keast and Webb 1966). Smaller individuals (less than 4 cm) eat chironomid larvae, ostracods, cladocerans, copepods, and small quantities of amphipods and even flying insects. Larger individuals take the same items, but also are known to eat Odonata and Ephemeroptera nymphs, molluscs, tubellarians, and small crustaceans (Keast and Webb 1966; Scott and Crossman 1973; Baker-Dittus 1978).

Prey selection relies on visual perception (Desgagné and Lalancette 1984) and feeding is as a member of a school (Keast and Webb 1966). Competition with *Fundulus hereroclitus*, where the two are sympatric, seems to be minimized by differences in diet and foraging patterns (Baker-Dittus 1978; Weisberg 1986).

Limiting Factors

The availability of suitable habitat and barriers to access may be limiting to the distribution of the species in Newfoundland and along the North Shore of the Gulf of St. Lawrence (Gibson and Sears 1977; Gibson et al. 1984). The lack of suitable habitat [clear lakes of glacial origin with much aquatic vegetation (Trautman 1957; Smith 1979) could be limiting further distribution in Manitoba as well. Clear water with abundant vegetation seems necessary to the survival of the species (Trautman 1957). Clear water may be important due to the reliance of visual perception in prey selection (Desgagné and Lalancette 1984) and vegetation may be important for predator avoidance (Godin and Morgan 1985), foraging patterns (Baker-Dittus 1978) and reproduction (Richardson 1939). Notwithstanding, there are still many lakes in both Manitoba and Newfoundland which would qualify as suitable habitat and which are also accessible to known collection sites, even to small fish with limited ability to ascend rapids etc. (J. Gibson, Department of Fisheries and Oceans, St. John's, Newfoundland; K. W. Stewart, Department of Zoology, University of Manitoba, Winnipeg, Manitoba; personal communications). Both K. W. Stewart and J. Gibson (personal communications) suggest that the species may be limited by temperature, i.e., the cooler waters of Manitoba and Newfoundland are colder than the 21° to 23°C necessary for killifish production. If this is the case, one might expect an increase in abundance and distribution if the recent warming trend continues. Other species (e.g. *Micropterus dolomieui, Morone chrysops,*

Poxomis nigromaculatus, Noturus flavus, Notropis spilopterus have demonstrated this trend in the last five to 10 years (K. W. Stewart, personal communication).

There are no indications of decline in Canadian populations; however the species has disappeared from significant portions of its former range in Ohio and Illinois, where it is thought that the destruction and general deterioration of natural lakes has led to this decline (Trautman 1957; Smith 1979). Although similar habitat disruption and deterioration has occurred in Ontario, for example, there is no evidence of a similar decrease in populations here, but there have been no serious, specific surveys to that end and it may well be that there have been losses in certain areas.

It is interesting to note that it seems to be the western form of the species that has shown evidence of decline in parts of the United States range. In Ohio, both forms are present, but it is apparently only the western form that has been affected (Trautman 1957). *Fundulus diaphanus menona* exists only from Illinois westward, and throughout the western part of the United States range, this subspecies seems generally to be in trouble (Miller 1972; Johnson 1987), perhaps due to increases in turbidity. Temperature and salinity preferences may bear some influence on the distribution of the species (Fritz and Garside 1974b; Garside and Morrison 1977; Melisky et al. 1980; Weisberg 1986) and *Fundulus diaphanus diaphanus* can tolerate brackish waters and apparently does well in them (Fritz and Garside 1975), but for some reason not yet determined, it shows a distinct preference for fresh water (Keast and Webb 1966; Griffith 1974; Fritz and Garside 1975). This might be related to competition with *Fundulus heteroclitus*. It may be that the eastern form has less stringent requirements for water quality and vegetation tha the western form and has not been affected to the same degree by habitat perturbations.

Competition with similar and/or related species for food or a niche does not seem to be limiting (Fritz and Garside 1975; Baker-Dittus 1978; Weisberg 1986), although *Labidesthes sicculus* is also a surface feeder. Predation by game fish, waterfowl or other fish-eating birds could limit populations in some areas (White 1953, 1957; Scott and Crossman 1973).

Chronic exposure to aquatic contaminants may produce physiological symptoms and death of fish. Studies of the effects of first generation herbicide and pesticide reagents have shown that many of these had many undesirable side effects and most have been withdrawn from use, although residues of some are persistent and will remain in the environment for some time (Rehwoldt et al. 1977). Second generation reagents commonly in use are more specific and shorter lived. Experiments carried out with Banded Killifish from the Hudson River indicate that there were no substantial effects to the species from chronic exposure to chlorinated hydrocarbons or organic phosphates at levels present in the river water (Rehwoldt et al. 1977).

Special Significance of the Species

Banded Killifish are interesting and colourful fish that do well in aquaria and may be useful to science in toxicology experiments, etc. They may be an important forage species to game fish in some areas and provide food for fish-eating birds as well. They are of little or no economic importance, but are sometimes used as bait fish in the Maritime Provinces. Absence of the species from former range may be indicative of changing water quality.

Evaluation

It appears that the species is widely distributed in Canada and, in most areas, is locally abundant. The species is known from only two locations in Manitoba where it is not abundant and has not been found elsewhere in the province despite various collection attempts. The species is extremely rare there, but contiguous with populations in Ontario, North Dakota, and Minnesota. Likewise in Newfoundland, the species has only been recorded from two widely separated localities, but appears to be more locally abundant than in Manitoba. It is unlikely that the distribution here is much broader than that already reported because of barriers (physical and climatic) to further immigration. Until further evidence proving a wider distribution and abundance for the species in Newfoundland is available, it should be considered rare and vulnerable in that province as these populations are discrete from other Canadian populations.

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Status of the Least Darter, *Etheostoma microperca*, in Canada*

KEN W. DALTON

8 Suffolk Street, Nepean, Ontario K2G 3P4

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Least Darters, *Etheostoma microperca*, are very small fish found in clear, quiet, well vegetated waters in central North America and the Ozark uplands. The Canadian distribution is restricted to southern Ontario although this is not the northern fringe of the species range. Both American and Canadian ranges have declined, but remaining Ontario populations seem to be stable. These fish do not presently appear to be vulnerable in Canada, but the status should be re-evaluated in a few years. Its need for clear water exposes the species to loss of habitat through human activities. Directed surveys are necessary for proper evaluation because of the Least Darters' small size and elusive habits.

Les petits dards, *Etheostoma microperca*, sont des minuscules poissons de la famille des percidés vivant dans les plans d'eau limpides et calmes où la végération est dense du centre de l'Amérique du Nord et des hautes terres des monts Ozark. Au Canada, ce poisson n'a été signalé que dans le sud de l'Ontario, bien qu'il ne s'agisse pas là de la limite septentrionnale de son aire de répartition. Même si, aux États-Unis et au Canada, ses aires de distribution se sont rétrécies, les populations qui persistent en Ontario semblent stables. Ces poissons ne semblent pas actuellement être vulnérable au Canada, mais il faudra réévaluer leur situation dans quelques années. L'espèce a besoin d'eau claire et la dégradation de son habitat à cause des activités d'homme l'expose en danger. Des études dirigées s'imposent afin d'évaluer de façon appropriée la situation des petits dards, car ils sont petits et ont tendance à se dissimuler.

Key Words: Least Darter, *Etheostoma microperca*, petit dard, darters, Percidae, rare and endangered fishes, status, Canada.

Least Darters, *Etheostoma microperca* Jordan and Gilbert 1887, (Figure 1) are among the smallest fish, and smallest vertebrates, found in Canada (Scott and Crossman 1973). Adults are only 25 mm in total length (TL), though females are larger than males and may reach 38 mm TL (Scott and Crossman 1973). Bodies of the fish are robust and laterally compressed. They have relatively small heads with equally small mouths, but moderately-sized to large eyes. Two dorsal fins are present, very close together. The most anterior of the two has six or seven relatively strong spines while the second holds eight or nine soft rays. The caudal fin is rounded and clearly barred. The anal fin is well developed with one or two spines. Pelvic fins are located low on the ventral surface, close behind the pectoral fins (Scott and Crossman 1973).

The fish are generally brown in colour, with darker brown spots on the back and sides. A distinct, but short, dorsal stripe is present anterior to the dorsal fins, and eight to 10 dark squarish blotches on each side. Males are colourful during breeding season, with intensely vivid red-orange pelvic and anal fins, and orange spots between the spines of the first dorsal fin (Scott and Crossman 1973; Kuehne and Barbour 1983). The only breeding colours exhibited by females are a yellowish tinge on the pelvic, pectoral, and anal fins (Scott and Crossman 1973).

Breeding males develop sheets of skin on their pelvic fins, which extend out, and give a slight concavity to these fins (Petravicz 1936). Nuptial tubercles are also present on the rays of pelvic fins on breeding males, particularly on the distal portions (Burr and Page 1979). Together, the two pelvic fins form a saddle-like structure used for mounting females (Petravicz 1936). Female Least Darters have a distinctive, swollen, conical genital papilla, close behind the anus, that can be used for sexing at all times of the year (Burr 1978).

Distribution

The Least Darter occurs in central North America, from southern Ontario west to the Michigan-Huron basin (Figure 2) and the southern tributaries of Lake Superior (Kuehne and Barbour 1983). The northern fringe of the range is in North Dakota and Minnesota. The range extends south as far as the Mississippi River system in Minnesota, and further south are disjunct populations in the Ozark Uplands; from central Missouri to southeastern Oklahoma (Kuehne and Barbour 1983).

In Canada, Least Darters are found only in southern Ontario (Figure 3a); in the western

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

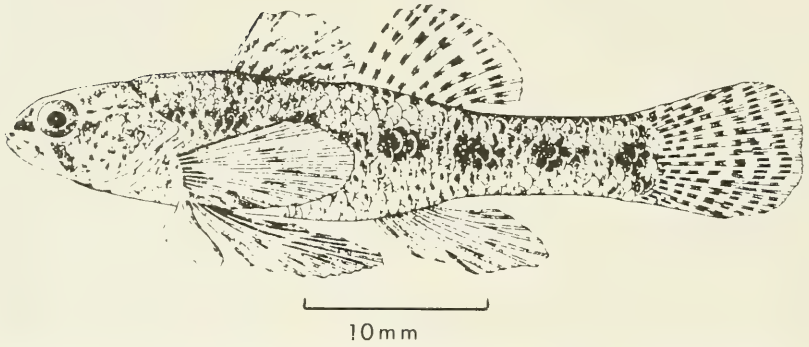

FIGURE 1. Least Darter, *Etheostoma microperca*, male (adapted from Burr and Page 1979).

tributaries of Lake Ontario, the drainage of Lakes Erie and St. Clair, and the southeast drainage of Lake Huron (Scott and Crossman 1973).

These small fish are often not detected in surveys because of their small size and secretive habits (Trautman 1957; Scott and Crossman 1973; Smith 1979). They may occur in some areas completely unknown to investigators until finally being discovered through lengthy, repeated sampling (Trautman 1957) or through the use of seines with a smaller than standard mesh size (Scott and Crossman 1973). A keen eye can detect their darting movements in clear water as they dive and swim into the sand. For these reasons, Trautman (1957) assumed that Least Darters probably had a more extensive, but undiscovered, range in the United States prairies before 1900, but is no larger present in the area because of extensive habitat modifications. The same can be true for many Lake Ontario tributaries.

The remote Ozark populations may have been, until recently, connected to the northern groups of *Etheostoma microperca* by an undetected population or series of populations (Kuehne and Barbour 1983). Pflieger (1971), however, has suggested that the Ozark groups are naturally separated from other populations of the species because of glaciation and geomorphological processes, and that Ozark populations are "glacial relicts."

Protection

Least Darters receive legal protection in the state of Iowa, but not in other states though the fish are of special concern in Kansas, Kentucky and Wisconsin (Johnston 1987).

The species receives no specific protection in Canada but is given incidental protection through the fish habitat sections of the Fisheries Act.

Population Sizes and Trends

No surveys of the Least Darter have taken place, thus populations sizes are difficult to assess. However, the presence or absence, and occasionally the relative abundance, can be inferred through collection records of the Canadian Museum of Nature (NMC), the Royal Ontario Museum (ROM), the Ontario Ministry of Natural Resources (OMNR), and others.

Only a few collections of *Etheostoma microperca* have ever been taken from Lake Ontario tributaries (Figure 3b). The presence (or former presence) has been indicated in the Moira River (ROM 24215),

FIGURE 2. North American distribution of the Least Darter, *Etheostoma microperca*.

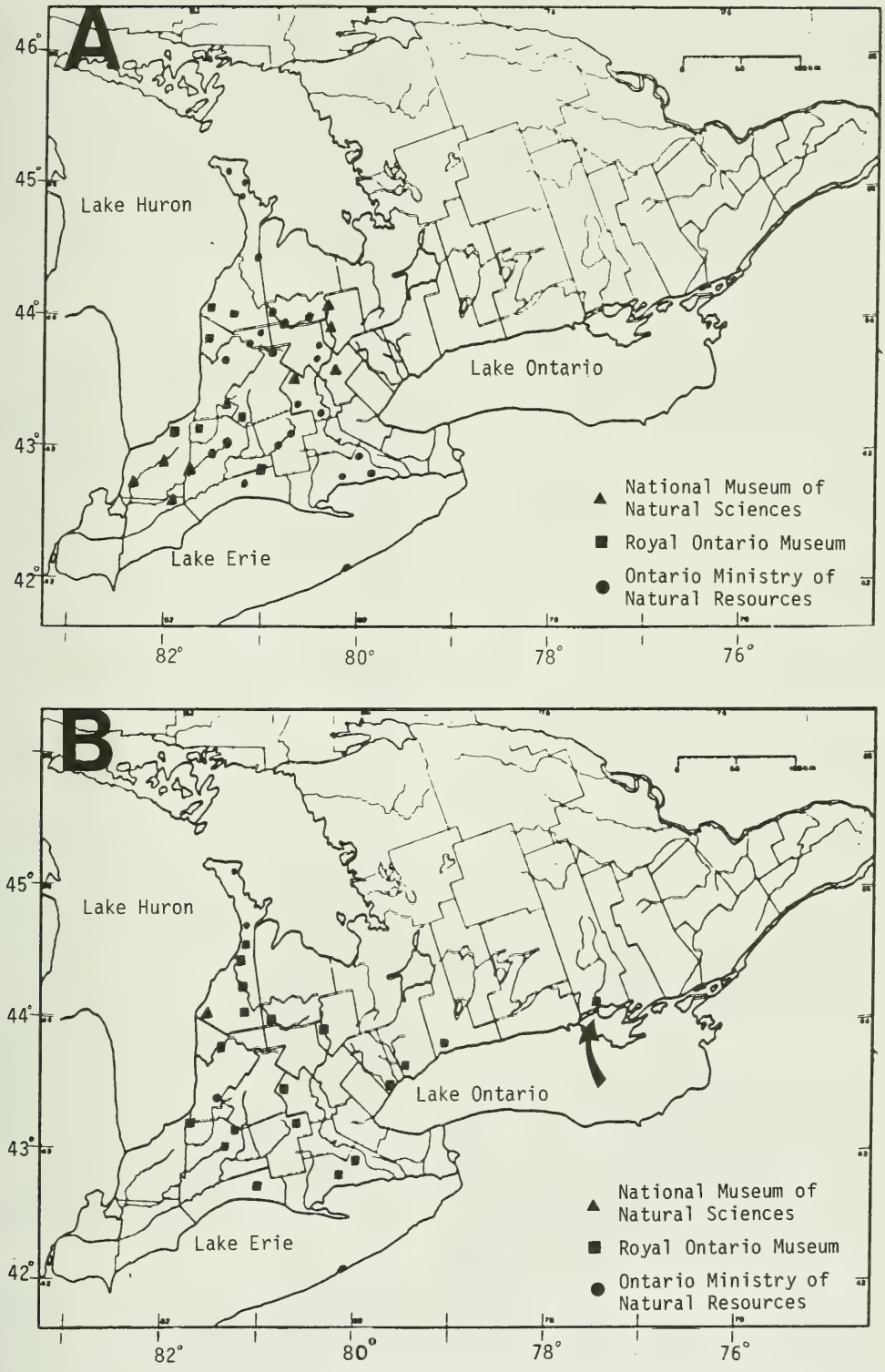

FIGURE 3. Collection records of *Etheostoma microperca* in Ontario: A. post 1970, B. pre-1970.

Duffins Creek (ROM 24454), the outlet from Grenadier Pond in Toronto (ROM 08534), and the Credit River (ROM 04334). The last of these collections was from Duffins Creek in 1965 (ROM 24454). Surveys carried out in these waters since 1965 have not yielded any Least Darters (Holm and Crossman 1986a, 1986b). The possibility of the species continued undetected presence in the region is very small because of extensive urbanization in much of the area with its accompanying pollution and habitat destruction.

Etheostoma microperca have not been recorded from the Sauble River since July 1958 (ROM 20120). The numbers captured at that time, 15 specimens, indicates a relatively good abundance. Probably, little habitat alteration has occurred in this river except near the mouth at Lake Huron. The apparent paucity of collections from the river is most likely due to a lack of sampling, and not because of a reduction in range or numbers of the species (R. R. Campbell, Department of Fisheries and Oceans, Ottawa, Ontario; personal communication). Another river in the same watershed, Arkwright Creek, appears to harbour Least Darters in at least three locations (OMNR S83). Although abundance can not be determined, the collections do indicate the continuing presence of Least Darters in the watershed.

There is no evidence for any reductions in range or population size elsewhere in Ontario (Figure 3a). The NMC, OMNR, ROM and others collected extensively in Ontario waters in the early to mid 1970s. Numbers taken, and the numerous collection sites reveal that Least Darters were then still widespread in southern Ontario, apart from the Lake Ontario drainage, and possibly locally abundant in parts of many rivers (Figure 3a). D. E. McAllister and J. Kar (NMC 85-0564) collected one 1.75 km northwest of Exeter, Ontario (43°24′45″N, 81°29′50″W) in July 1985 in the Ausable River and sighted a few others. Much of this river is too heavily sedimented now for this species.

Habitat

Greatest abundance of Least Darters occurs in clear quiet, weedy waters of lakes and slow-moving rivers (Scott and Crossman 1973; Burr 1980; Kuehne and Barbour 1983). Muddy substrates or sand, or mixtures of the two, are found at these sites (Scott and Crossman 1973; Burr 1980; Page 1983). Trautman (1957) described preferred habitat as the clearest of waters with muck bottoms (= natural organic silt, not man-induced), debris, gravel, but not yellow clayey silts.

These habitat types are probably widespread throughout the range of the species but could be threatened by development of water resources, such as drainage, channelization, construction of beaches, filling, soil tillage, and other alterations. Trautman (1957) assumed that such activities have caused a reduction in the abundance and range of the species in the United States prairies.

Trends in the quality of habitat are unknown, but since the range of Least Darters in Canada is in one of the most heavily populated areas of the country, it is reasonable to suppose that the quantity of habitat may be decreasing. The disappearance of the species from Lake Ontario tributaries may be an example of such declines.

General Biology

The lifespan of Least Darters is quite short; as little as 18 months for males and 20 months for females (Burr and Page 1979). Both sexes are mature, and spawn, at 1 year of age (Burr and Page 1979). Breeding in Canada probably occurs in May and June, although no published data on the subject has been found (Scott and Crossman 1973).

Reproductive behaviour is unusual relative to other etheostomatins. Petravicz (1936) concluded from the numbers of each sex that he collected from shallow inshore waters and from deeper waters, that females stay in deep waters until ready to spawn while male darters enter shallow, heavily vegetated inshore waters during the breeding season. Petravicz (1936) noted that males do not establish territories, but do show resentment toward other males. Winn (1958b: *as cited by* Burr and Page 1979) observed that males defend small, three-dimensional territories, about 30 cm in diameter, although defense wasn't sustained through the night. Pugnacious behaviour between rival males, described by Burr and Page (1979), supports Winn's (1958b) observations. Winn (1958a) indicated that tank conditions affect the behaviour of many species of darters, and that crowding causes the breakdown of sex recognition in *Etheostoma microperca*. This variable behaviour may have caused these conflicting observations.

In natural conditions, when a female is ready to spawn she will enter the shallow waters of the males' domain and make herself conspicuous (Petravicz 1936). Several males attempt courting and a chase ensues while the female looks for a suitable site for egg deposition, usually a vertical or inverted surface on aquatic vegetation (Petravicz 1936; Burr and Page 1979). Eventually, one male, usually the largest and most colourful, succeeds in driving away his competitors (Petravicz 1936). When the female comes to rest motionless at her selected breeding site, the dominant male mounts her on the dorsal surface in a parallel position, using his enlarged pelvic fins as a clasping organ (Petravicz 1936; Burr and Page 1979). Vibration is initiated by the male but is quickly matched by the female (Petravicz 1936). During the short few seconds of vibration, the

bodies of each of the pair curve, a single adhesive egg is laid, and sperm are released near the egg (Petravicz 1936). Burr and Page (1979) found several eggs at each site, laid in three or four quickly repeated spawning acts. A few minutes after egg deposition, the female will find a new breeding site, and the pair will spawn again (Petravicz 1936).

Spawning is continued from dawn till noon, or early afternoon, and each female lays about 30 eggs in one day (Petravicz 1936). Winn (1958b: *as cited by* Burr and Page 1979) reported pre-spawning female egg counts from 455 to 1102. No parental protection is provided to the eggs (Brooks and Page 1979).

Vertical and inverted spawning are remarkable feats for any fish, but especially for these darters which have no air bladder to control their buoyancy (Petravicz 1936). To maintain position on the breeding site, and on each other, Least Darter pairs rapidly vibrate their pectoral and caudal fins, and the male also vibrates his posterior dorsal fin (Petravicz 1936). Petravicz (1936) also observed horizontal spawning on the substrate but only in artificial conditions; aquaria that held few plants and a fine sand bottom.

Food is chiefly small crustaceans and larval chironomids (Petravicz 1936; Burr and Page 1979; Paine et al. 1982). Other small benthic organisms found in stomachs of specimens examined by Burr and Page (1979) include gastropods, annelids and insects. The long caudal peduncle and pectoral fins, the laterally compressed body, and the small anteriorly opening terminal mouth are adaptations for capturing small, active prey, among plants (Paine et al. 1982).

Burr and Page (1979) found no evidence of large-scale migration up or down stream. Winn (1958a) observed the populations of Least Darters in his study area, Whitmore Lake, Michigan, which is a lake with a muddy, organic debris laden bottom, moved from the deeper mucky areas to shallow shore water in April. This observation seems to imply that the species overwinters in deep, muddy water, when it is available, and agrees with Petravicz's (1936) observations on reproductive behaviour.

Etheostoma microperca is hardier than many other fishes in drought conditions. The species survives extremely dry periods by burrowing into the substrate and waiting until more favourable conditions return (Tramer 1977: *as cited by* Burr and Page 1979).

Limiting Factors

The distribution and range of Least Darters are controlled by several natural factors. In the Ozarks, the complementary distribution of Least Darters and Cypress Darters, *Etheostoma proeliare*, may have been caused by competition between the two species (Pflieger 1971). Substrate type and current velocity exclude Least Darters from the Ozark lowlands (Pflieger 1971). Clear, upland streams are the natural habitat of the species. Large rivers, even those connecting the Ozarks and the northern range of the species, are barriers to dispersal of *Etheostoma microperca* (Pflieger 1971).

Water temperature appears to limit the northern range of the species (Burr 1978).

Habitat destruction, due to human activities, has caused population losses as well as reductions. Northern Ohio streams that have been dredged have suffered population losses or destruction (Trautman 1957). Other human practices that have deleterious effects on fish habitats are listed by Pflieger (1971): ditching, drainage of swamps and other still waters, impoundments, channelization, changing flow regimens.

Pollutants from industrial and domestic activities, such as extensive pesticide and fertilizer use, also have deleterious effects on populations of Least Darter (Pflieger 1971). Shoreline development by cottagers, road construction etc., can cause increased soil erosion, resulting in higher turbidity levels, as well as reduction of the littoral zone of waterbodies, lessening the breeding area of Least Darters and the productivity of waterbodies in general.

Special Significance of the Species

Least Darters do not have any known economic value and their importance to the ecology of freshwater systems is unknown and difficult to determine (Scott and Crossman 1973). Burr (1978) asserts that *Etheostoma microperca* is probably the most advanced member of the family Percidae and certainly the most advanced of the sub-genus *Microperca*. He recognized the species as monotypic but noted that several populations are in the process of genetic differentiation. These postulations may give the species importance in the study of evolutionary and speciation processes. Breeding habits are believed to warrant further study. Vertical and inverted spawning habits are unusual and may indicate a niche specialization (Scott and Crossman 1973). Winn (1958a) draws attention to the manner in which breeding habits change according to environmental conditions and states that the Least Darter's breeding behaviour is influenced in a complex manner by their size, as well as by environmental and genetic factors.

Evaluation

The range and numbers of *Etheostoma microperca* appear to have been reduced in parts of the United States. Trautman (1957) assumed that populations in Ohio were reduced because of

habitat destruction. In 1972, Miller reported that the fish was rare in Kansas and endangered in Pennsylvania. More recently, Johnson (1987) stated that the species receives legal protection in Iowa and is of special concern in Kansas, Kentucky and Wisconsin.

Least Darters are close to the northern fringe of their North American range in Canada. In the past several decades, the Canadian range appears to have contracted (Figure 3) due to habitat loss and degradation and, at present, the fish are found only in southwestern Ontario. Populations remaining in Canada appear to be healthy and stable and the range no longer seems to be shrinking.

For the present, the species seems to be secure in Canada. However, its status should be re-evaluated in the near future, and, because of its small size and elusive habits, directed surveys are needed.

Acknowledgments

Many thanks are extended to G. Gale of OMNR and E. Holm of ROM for supplying information about collections of Least Darters by their respective organizations. I would especially like to thank D. E. McAllister, Canadian Museum of Nature, for providing collection record data as well as published literature concerning the species. R. R. Campbell is thanked for providing support and advice and R. E. Campbell for typing the manuscript.

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Status of the River Darter, *Percina shumardi*, in Canada*

KEN W. DALTON

8 Suffolk Street, Nepean, Ontario K2G 3P4

Dalton, Ken W. 1990. Status of the River Darter, *Percina shumardi*, in Canada. Canadian Field-Naturalist 104(1): 59–63.

The River Darter, *Percina shumardi,* is a small percid of larger streams, rivers, and some inland lakes of Manitoba and northwestern Ontario, in Canada, as well as in the United States. The species is also known from the Lake St. Clair drainage of southwestern Ontario. Very little is known of the biology or ecology of the species in Canada and it does not seem to be abundant anywhere, although populations appear to be stable.

Le Dard de rivière, *Percina shumardi*, est une petite espèce de la famille des percidés qui fréquente les grands cours d'eau, les rivières et certains lacs intérieurs du Manitoba et du nord-ouest de l'Ontario au Canada, et l'espèce est aussi trouvé aux Etats-unis. On trouve également l'espèce dans le bassin de drainage du lac Sainte-Claire dans le sud-ouest de l'Ontario. On connaît très peu de choses sur la biologie ou l'écologie de l'espèce au Canada et elle ne semble abondant nulle part, bien que les populations semblent stables.

Key Words: River Darter, *Percina shumardi*, dard de rivière, Percidae, darters, rare and endangered fishes, status, Canada.

River Darters, *Percina shumardi* (Girard 1860), are small fish (Figure 1) of the family Percidae (subfamily Etheostomatinae). They have slender but sturdy bodies and grow to about 58 mm total length in Canada (Scott and Crossman 1973). Longer lengths (to about 65 mm) have been reported for the fish in American waters (Cross 1967; Thomas 1970; Smith 1979; Kuehne and Barbour 1983). The species has a large head with a short rounded snout and a moderately sized, terminal mouth (Trautman 1957; Scott and Crossman 1973). The large eyes are close together, high on the head (Kuehne and Barbour 1983).

The dorsal fins are close together, the first having hard spines, while the second has soft rays (Trautman 1957; Scott and Crossman 1973), the caudal fin is slightly forked. Pelvic fins are of moderate size and are pointed and insert on the ventral side close behind the pectoral fins and are a small distance apart (Trautman 1957; Cross 1967). Each contains one "head" spine anteriorly, followed by five soft rays (Cross 1967). Pectoral fins are fan shaped and have soft rays but no spines. Two spines are found on the anal fin, followed by 11 to 13 rays (Scott and Crossman 1973).

The overall colouration of the River Darter varies from light brown to dark olive and many markings decorate the body. Seven or eight indistinct saddle marks adorn the dorsal surface and eight to ten dark lateral blotches appear on the sides, often as short vertical bars. Distinct suborbital bars drop from the eyes, and small, well-defined, caudal spots may be present (Scott and Crossman 1973).

Colouration on breeding males is generally darker, and pigmented areas are more conspicuous. Posterior rays of the anal fin extend almost to the base of the caudal fin (Scott and Crossman 1973; Kuehne and Barbour 1983). Breeding males may also develop nuptial tubercles on the caudal, anal and pelvic fins, as well as on the vent and on the head along the infraorbital and preopercular mandibular canals (Kuehne and Barbour 1983).

Distribution

River Darters have a very large latitudinal distribution (Figure 2), from Sipiwesk Lake in Manitoba, south to the Texas coast of the Gulf of Mexico (Scott and Crossman 1973: 1983). The Canadian range of the River Darter includes two provinces (Figure 3); collection records of the National Museum of Natural Sciences, now Canadian Museum of Nature (NMC), the Ontario Ministry of Natural Resources (OMNR), the Royal Ontario Museum (ROM) and the Province of Manitoba were accessed, in addition to literature records.

In Ontario, it occurs from the Kenora district to as far north as Lake Attawapiskat and Sandy Lake (Scott and Crossman 1973). The species is also known from the Lake St. Clair drainage: a Sydenham River collection was made in 1975 (OMNR 582) and one from St. Luke's Bay in Lake St. Clair itself (ROM 48870) in 1985.

In Manitoba, the species occurs in scattered locations in the Lake Winnipeg drainage as far

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

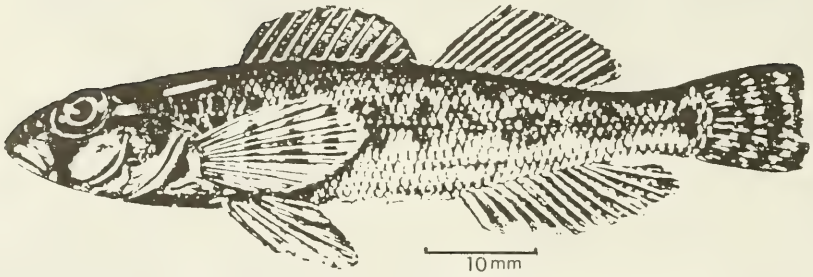

FIGURE 1. River Darter, *Percina shumardi* (adapted from Cross 1967).

north as Sipiwesk Lake and as far west as Lake Dauphin and the Red River (Scott and Crossman 1973).

Protection

River Darters are legally protected in the State of Ohio but not elsewhere in the United States, although the species is given special concern in Kansas, Kentucky, North Dakota, and West Virginia (Johnson 1987). In Canada, *Percina shumardi* have no specific protection, but incidental protection is provided by the Fish Habitat Section of the Fisheries Act.

Population Sizes and Trends

Percina shumardi does not seem to have ever been abundant in Canadian waters (Scott and Crossman 1973). Not many collections have been made in Canada (NMC, OMNR, ROM records), and usually only one or two fish have been taken from a site, the most in a single collection being 10 specimens. The fish's range includes some relatively remote areas of the country and the paucity of collection records may be a reflection of this. It may also be a result of difficulty encountered in sampling the species' favoured habitat, large rivers with fair to moderate currents and a rocky substrate.

Most Ontario records of River Darters are from lakes in the northwest of the Province; only two Ontario records actually come from rivers (Vermilion Creek, ROM 07709; Sydenham River (east), OMNR 582). The latter, and the collection from St. Luke's Bay, may indicate a range expansion into Lake St. Clair and southern Ontario. Scott and Crossman (1973) had earlier suggested the possibility of a southwestern Ontario distribution based on records from the Detroit River.

Actual numbers of River Darters in Canadian waters cannot be estimated. The species seems to be naturally rare in Ontario and Manitoba, although they may exist undetected in many rivers. Records, although few and far between, seem to indicate stable populations in both provinces.

In the United States, the distribution is widespread in the Mississippi system but the species has never been detected in abundance (Trautman 1957). The status of the species is considered to be of special concern in most U.S. states where it occurs (Johnson 1987).

Habitat

River Darters are chiefly found in large rivers with rocky substrates and fair to moderate currents (Thomas 1970; Scott and Crossman 1973). Large individuals have also been taken from strong currents (Page 1983). Thomas (1970) collected the fish mostly from deep riffles and chutes, and only found young fish in water 60 cm deep or shallower. River Darters also inhabit lakes (Scott and Crossman 1973) and in Ontario are more commonly found in lacustrine environments. Smith (1979)

FIGURE 2. North American range of the River Darter, *Percina shumardi* (adapted from Kuehne and Barbour 1983).

FIGURE 3. Distribution of the River Darter, *Percina shumardi*, in Canada; A - collections pre-1975, B - collections post-1975.

- ● Ontario Ministry of Natural Resources (OMNR)
- ■ Royal Ontario Museum (ROM)
- ▲ Canadian Museum of Nature (NMC)
- □ Province of Manitoba

reports the fish infrequently occurs in clear, sandy channels close to large rivers.

General Biology

No information about the spawning behaviour of River Darters in Canada is available. On the Neoshi River, Kansas, Cross (1967) captured River Darters that seemed to be spawning below a low dam in clear water about 61 cm deep, over a bedrock substrate littered with gravel and large stones. Scott and Crossman (1973) presumed that, in Canada, breeding occurs in the the spring, possibly during the months of June and July. The authors also assumed that spawning behaviour is similar to that of other members of the genus *Percina, P. copelandis* and *P. maculata* in particular. Breeding of these two species, as reported by Scott and Crossman (1973), has several common features that may be shared by River Darters. The female wriggles her body into gravel and then the male perches on top of her, resting his caudal fin beside hers. Eggs are laid, fertilized, and deposited from that position and given no parental care. The fish are promiscuous and females will mate with several partners during the breeding season.

The breeding age of the species, and the number of eggs laid by River Darters, are unknown.

No direct observations of feeding by River Darters have occurred in Canada. Thomas (1970) found that, in the lower Kaskasia River, Illinois, the fish principally ate chironomid and hydropsychid larvae and also took other insects, microcrustaceans, and fish eggs. Starmes (1977, *as cited by* Kuehne and Barbour 1983) and Thomson (1974, *as cited by* Page 1983) state that snails, when available, from a large part of the diet of *P. shumardi*.

The age attained by River Darters in Canada is unknown; most of those in Illinois die at three years of age, although some may reach four years (Smith 1979).

Movement by River Darters is generally unknown; however, twice, when the Scioto River, Ohio, was in flood, Trautman (1956) captured a single adult in flood water a good distance from the river channel, and suggested that they were migrating upstream.

Limiting Factors

The River Darter is believed to be limited to large streams and lakes (Thomas 1970; Kuehne and Barbour 1983). It is more tolerant of turbidity than other darters (Pfleiger 1975), and even seems to prefer shallow water in turbid locations (Trautman 1957).

Pollution does not appear to be a major limiting factor in the western Canadian range of River Darters, but could be limiting in southwestern Ontario. Thomas (1970) reports a few dramatic cases where pollution killed many fish, including River Darters, in Illinois. Impoundments have led to the extirpation of the fish from some American rivers (Thomas 1970; Kuehne and Barbour 1983) as have dredging and channelization (Thomas 1970).

Special Significance of the Species

River Darters span a large climatic and latitudinal range, from the Gulf of Mexico in Texas to Sipiwesk Lake in northern Manitoba (Kuehne and Barbour 1983). They have no known public interest or economic importance.

Many darters of the genus *Percina* are of special concern, and some are legally protected in various U.S. states (*see* Johnson 1987).

Evaluation

River Darters appear to be rare in Canada, and although populations seem to be stable, their status could change rapidly if habitat destruction occurs. Populations should be monitored to detect change, but at present the species does not appear to be under any immediate threat nor to warrant vulnerable status.

Acknowledgments

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Status of the Redbreast Sunfish, *Lepomis auritus*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

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The Redbreast Sunfish, *Lepomis auritus*, is one of the smaller centrarchids. The native range is confined to the Atlantic drainage east of the Appalachians. In Canada, the species is found only in New Brunswick where it has a restricted distribution. It is often overlooked because of its small size and its similarity to smaller members of other centrarchid species. Due to the restricted range and the potential for habitat pollution by industrial, urban, agricultural and silvicultural contaminants, the species should be considered vulnerable in Canada.

Le crapet rouge, *Lepomis auritus*, est l'un des centrarchidés les plus petits. Le territoire de l'espèce est limité au bassin versant de l'Atlantique à l'est des Appalaches. Au Canada, on ne trouve le crapet rouge qu'au Nouveau-Brunswick où son aire de répartition est restreinte. Ce poisson passe souvent inaperçu en raison de sa petite taille et de sa ressemblance avec les plus petits membres d'autres espèces de centrarchidés. A cause de son territoire limité et des risques de contamination des bassins versants qu'il occupe par des polluants industriels, urbains, agricoles et forestiers, l'espèce doit être considérée comme vulnérable au Canada.

Key Words: Redbreast Sunfish, *Lepomis auritus*, crapet rouge, Centrarchidae, sunfishes, New Brunswick, rare and endangered fishes, status, Canada.

The Redbreast Sunfish, *Lepomis auritus* (Linnaeus 1758), is one of the smaller members of the sunfish family (Centrarchidae). These fish (Figure 1) usually range from 12.7 to 17.8 cm in length but individuals as large as 20.3 cm have been reported from New Brunswick and 23.9 cm in Connecticut (Scott and Crossman 1973). The large Connecticut individual weighed 312 g but the usual range is around 165 to 232 g (*see* Carlander 1977). Redbreast Sunfish have a deep, laterally compressed body with a narrow caudal peduncle. The distinctive opercular flap is larger in adult males than in juveniles or adult females and is black with no distinctive border.

The body is golden brown to olivaceous, the dorsal surface being darker. The sides are lighter in colour showing indistinct red spots and blue streaks, particularly on the side of the head. The breast, as the name implies is usually red, but may vary from yellow to orangish-red. The colour is intensified in breeding males. Fins may be dusky or darkly mottled, the leading edges and tips of the pectorals are dark (*see* Scott and Crossman 1973).

The species may be confused with the Longear Sunfish (*Lepomis megalotis*) or the Pumpkinseed (*Lepomis gibbosus*), but the longer opercular flaps of adult male Redbreast Sunfish are not bordered with white or colour. Females and smaller individuals may also be identified by the presence of palatine teeth which are not found in the Longear Sunfish (Scott and Crossman 1973). However, the ranges of the Redbreast and Longear sunfishes do not overlap in Canada.

As an economically unimportant sunfish the species is often overlooked, especially where larger species occur in the range. This, along with confusion with the Longear Sunfish may lead to erroneous assumptions regarding its abundance.

Distribution

The Redbreast Sunfish is one of the few native lepomin sunfishes occurring east of the Appalachians (Lee 1980). The native range (Figure 2) extends from New Brunswick (in Canada) south along the Atlantic slope to central Florida. The species is not normally found west of the Appalachians and in the south the native range extends west of the Choctawhatchee and Apalachicola rivers (Scott and Crossman 1973; Lee 1980). The Redbreast Sunfish has not been recorded from the state of Mississippi, but has been introduced into several lakes outside of the normal range, particularly in Texas and Oklahoma (Scott and Crossman 1973) and also northern Italy (Lee 1980).

In Canada, the species is known only from New Brunswick where it has been found in the Canaan, Oromocto, Magaguadavic, and Kennebecasis river systems as well as Anne, Oromocto, and Yoho lakes (Gorham 1970; Scott and Crossman

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

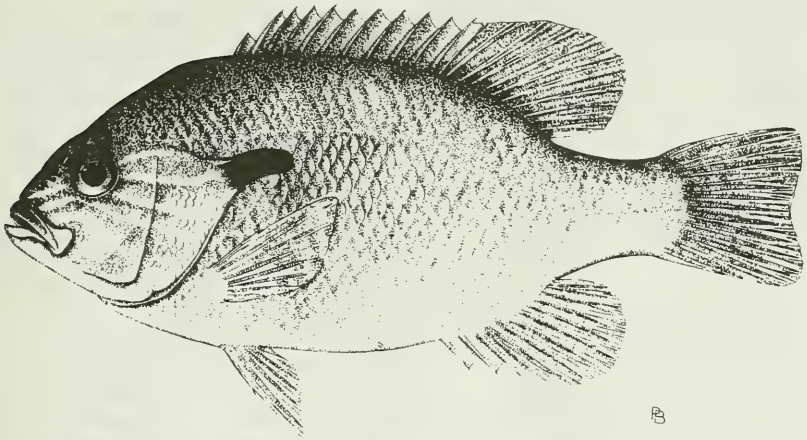

FIGURE 1. Redbreast Sunfish, *Lepomis auritus* [drawing by P. Buerschaper, from Scott and Crossman (1973) by permission].

1973). It may have a wider distribution, but because it is small and may readily be confused with other sunfishes, particularly the Pumpkinseed, its correct identification could have often been overlooked. One would expect, however, that serious collectors would have noted its presence.

Protection

No specific protection measures are offered the species although general protection is given under the Fisheries Act and the New Brunswick Provincial Endangered Species Act.

Population Sizes and Trends

Very little information is available on the distribution and abundance of the Redbreast Sunfish in New Brunswick. Collection records for the species are presented in Table 1. It has been suggested that the species has been known in New Brunswick since at least 1896 (Cox 1896). The first authentic record dates from 1948 (Scott and Crossman 1973).

The rarity of records may be indicative of natural rarity of a peripheral species, or could be due to lack of interest in the species and confusion with the Pumpkinseed. The more probable situation is likely to be a combination of these factors. No recent records (1980 on) are indicated but the species has definitely been taken in Oromocto Lake at various times between 1960 and 1979.

Habitat

The Redbreast Sunfish appears to be adaptive to a wide range of habitats. In New Brunswick, the species inhabits streams and lakes with rocky bottoms. In streams they occupy the slower deeper areas over rocks and gravel, in lakes they occur most abundantly on rocky shoals or in deeper, quieter water with sand or mud bottoms and emergent vegetation (Scott and Crossman 1973). The species tends to be more of a riverine species than other sunfishes (Lee 1980) and the description of nesting sites in Pennsylvania (Buynak and Mohr 1978) indicates that habitat requirements there are similar to those in New Brunswick. However, in Georgia the species frequents streams of the coastal plain characterized by low pH (4.5 to 6.0) with periods of extreme high and low flows (Coomer et al. 1977). Bottom substrates are usually of sand, sandstone and rubble.

In summer the fish appear to be widely distributed but aggregate in schools in deeper waters for the winter when water temperature falls below 5°C (Breder and Nigrelli 1935; Scott and Crossman 1973). In spring they migrate to shallow areas of lakes (15 to 46 cm) or downstream of rapids in streams for spawning when water temperatures go above 16.7°C, dispersing for the summer following spawning. The species has been reported to spawn in brackish, tidal waters in some locations where water temperature, salinity and depth vary considerably (Richmond 1940).

General Biology

There is very little published on the biology of the species in Canada. Scott and Crossman (1973) have summarized information on the biology and ecology of the species in the northern parts of the range. Redbreast Sunfish spawn in the spring or early summer when water temperatures are above 16°C (Scott and Crossman 1973). They overwinter in schools (Breder and Nigrelli 1935) in areas of deeper water and begin to move to shallower waters when water temperature rises above 10°C (Breder 1936; Breder and Rosen 1966). Spring

FIGURE 2. Native North American range of the Redbreast Sunfish (*Lepomis auritus*).

spawning migrations appear to be differentiated by sexes, the males making their way to the shallows first. The males establish territories and build nests (redds), which may be 60 to 100 cm in diameter and in water 15 to 46 cm in depth (Scott and Crossman 1973). Females leave the area after the eggs are laid, the males remain to guard the redd, fanning the nest to prevent suffocation and possibly guarding the larvae until swimup (Scott and Crossman 1973).

In lacustrine areas the redds may be close together in the open, but in streams they are in the current downstream of a protecting rock. They may also utilize unused redds of other centrarchids (Scott and Crossman 1973). Not surprisingly, Redbreast Sunfish have been known to hybridize with other centrarchids (*see* Carlander 1977) including the Bluegill (*Lepomis macrochirus*), the Redear Sunfish (*Lepomis microlophus*), Green Sunfish (*Lepomis cyanellus*), and the Pumpkinseed.

The number of eggs per female increases with age and size, but ranges from 1000 to 8000 (*see* Carlander 1977). The eggs are about 2 mm in diameter, amber in colour, and are adhesive (Scott and Crossman 1973; Carlander 1977; Buynak and Mohr 1978). Fertilized eggs collected from the wild hatched in three days when retained at 20 to 24°C (Buynak and Mohr 1978). Newly hatched larvae averaged 4.9 mm in length and by swimup averaged 7.9 mm. Other information and descriptions of Redbreast Sunfish larvae are also mentioned by Buynak and Mohr (1978). Age, weight and length data are presented by Carlander (1977). Growth appears to be rapid, not sexually differentiated, and maturity is reached at about 23 g in the second year (*see* Carlander 1977). Growth is apparently slower in the northern parts of the range (Carlander 1977). In New Brunswick, maximum size is about 20 cm, but the average is 13 to 18 cm with approximate weights of 165 to 232 g. In Connecticut, they are said to be larger, up to 24 cm in length and 312 g in weight (Scott and Crossman 1973; Carlander 1977). Longevity is not known, but individuals to age eight have been recorded (Carlander 1977).

Redbreast Sunfish feed primarily on small aquatic insects, but adult insects, molluscs, benthic invertebrates and even small fish may be consumed (Scott and Crossman 1973; Coomer et al. 1977). The species actively selects chironomids throughout the year, but are opportunistic feeders taking anything of the proper size which is available (Coomer et al. 1977). Lauder (1980) has described the feeding mechanism of these and other sunfishes.

Brown Bullhead (*Ictalurus nebulosus*), Chain Pickerel (*Esox niger*) and American Eel (*Anquilla rostratra*) are the main predators in the Canadian range (Scott and Crossman 1973). In other parts of the range the species may be prey to any of the larger piscivores present. Many fishes will take the eggs from unguarded nests (Scott and Crossman 1973). Hoffman (1967) has listed parasitic infections.

Limiting Factors

There is no information available on limiting factors for this species which appears adaptable to a wide range of ecological conditions. They do well in water of pH 4.8 to 8.4, salinity to 8% and water temperature to 37°C (*see* Carlander 1977). They tend to do better in uncrowded conditions with few predators.

The species requires clean water and, like most other fishes, does not fare well in polluted waters. No reliable information of the effects of aquatic contaminants on the species in the New Brunswick range is available, but these waters are subject to chemical pollution from industry (particularly the pulp and paper industry), agricultural runoff, urban wastes and pesticides (silviculture insect control programs).

Special Significance of the Species

Due to its small size the species is one of the least important (to man) sunfishes. In Canada and New Brunswick, lepomin sunfishes and other warm water fishes are not highly regarded as food or sport fish. However, they will take live bait and if

TABLE 1. Collection records of *Lepomis auritus* in Canada (New Brunswick) to March 1988. ROM = Royal Ontario Museum, NBM = New Brunswick Museum, NMC = National Museum of Natural Sciences, NBNRDS = New Brunswick Department of Natural Resources Data System.

Catalogue #	Location	Latitude	Longitude	Date	Number in Collection
—	Canaan River	—	—	03/09/48	—
ROM 22087	Oromocto Lake	45°36′90″N	67°00′90″W	14/08/61	—
ROM 22085	Oromocto River	—	—	24/06/62	—
NBM 0001	Oromocto River	45°36′00″N	65°55′00″W	1960	1
NBM 0011	Oromocto River	45°51′00″N	66°29′00″W	1960	1
NBM 0119	Kings County	—	—	30/05/66	—
NBM 0399	Rusagonis Stream	45°49′00″N	66°32′00″W	30/07/67	10
NBM 0494	Rusagonis	45°48′00″N	61°37′00″W	25/05/68	4
NBM 1068	Oromocto Lake	45°24′00″N	66°38′00″W	1979	—
NMC 67-0015	Anne Lake	45°25′00″N	66°13′00″W	15/07/66	4*
NMC 67-0322	Anne Lake	45°25′00″N	66°13′00″W	28/08/67	11
NMC 68-0072	Anne Lake	45°25′00″N	66°13′00″W	03/07/67	3
NBNRDS	Oromocto Lake (St. John River)				P**
NBNRDS	Yoho Lake (St. John River)				P
NBNRDS	Modsley Lake (St. Croix River)				P
NBNRDS	Knockdrin Lake (East Musquash River)				P
NBNRDS	Shadow Lake (East Musquash River)				P

*Also catalogued by NBM as 0155.
**P = Present.

fished with light tackle, can provide interesting fishing (Scott and Crossman 1973). The fish are good test animals and can be easily maintained in captivity (Carlander 1977). It is doubtful that they would ever become a popular aquarium fish. Some may be taken incidentally from the lower Saint John River and sold in the Farmer's Market at Saint John (M.A. Redmond, New Brunswick Department of Natural Resources, Fredericton, New Brunswick; personal communication).

Evaluation

The Redbreast Sunfish appears to inhabit the northern fringe of its North American range in New Brunswick. The species is restricted to drainages of the Atlantic seaboard but has been successfully introduced into areas outside of the native range. Although populations are locally abundant (Scott and Crossman 1973), they are known in Canada from only a few localities in New Brunswick where there is a high potential of environmental risk from water borne contaminants resulting from industrial, agricultural and silvicultural use of toxic chemicals. Due to the very restricted range and the potential risk of contamination in the watersheds where the species exists, the Redbreast Sunfish should be considered 'Vulnerable' in Canada.

Acknowledgments

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Status of the Orangespotted Sunfish, *Lepomis humilis*, in Canada*

DOUGLAS B. NOLTIE

School of Natural Resources, Fisheries and Wildlife Program, 112 Stephens Hall, University of Missouri — Columbia, Columbia, Missouri 65211.

Noltie, Douglas B. 1990. Status of the Orangespotted Sunfish, *Lepomis humilis*, in Canada. Canadian Field-Naturalist 104(1): 69–86.

The Orangespotted Sunfish, *Lepomis humilis*, has only recently been described as a member of the fish fauna of Canada. Given this novelty, a detailed description of the species is provided. Some morphological distinctions exist between specimens from Canadian and American populations. Although common and widely distributed in the United States, its known range in Canada is restricted to only three locations in southwestern Ontario. Evidence presented suggests that the species is native to the Lake Erie basin but that Canadian populations may have arisen through direct range expansion northwards out of Ohio. Population estimates and trends have not been established, but prospects for the species' long-term establishment in Ontario appear good given trends in southern populations. The species' habitat in Ontario is primarily low-gradient, slow-flowing streams having turbid waters, silt, clay or mud bottoms, and minimal submerged aquatic vegetation, a feature shared with more southerly populations. The changing face of southwestern Ontario stream habitats has favoured their invasion, and continuing agricultural impact bodes well for the numerical and geographical increase of the species in Canada. At present, the species is subject to no specific protection. A species of great beauty among Canadian fishes, a designation of vulnerable is suggested given its low numbers and extremely limited distribution.

Le crapet menu, *Lepomis humilis*, est présenté comme une espèce relativement nouvelle parmi les poissons du Canada. Étant donné qu'il s'agit d'une nouveauté, on donne une description détaillée de l'espèce. Certaines différences morphologiques existent entre les spécimens provenant des populations canadiennes et américaines. Bien que ce poisson soit largement répandu aux États-Unis, son aire de dispersion connue au Canada est limitée à trois endroits seulement au sud-ouest de l'Ontario. Les faits présentés portent à croire que l'espèce est indigère au bassin du lac Erié mais que ces populations canadiennes semblent être apparues grâce à une expansion directe de l'aire de dispersion vers le nord à partir de l'Ohio. On n'a pas établi d'estimations ni de tendance des populations, mais les perspectives d'établissement à long terme de l'espèce en Ontario semblent bonnes, étant donné les tendances observées dans les populations du sud. En Ontario, cette espèce fréquente surtout des cours d'eau turbides à courant faible, et à inclinaison peu prononcée dont le fond est constitué de limon, d'argile ou de vase et où il y a un minimum de végétation aquatique submergée, caractéristiques qu'elle partage avec les populations plus méridionales. Les changements de l'habitat des cours d'eau du sud-ouest de l'Ontario ont favorisé leur invasion et les répercussions constantes de l'agriculture augurent bien pour l'expansion numérique et géographique de l'espèce au Canada. Pour le moment, l'espèce ne bénéficie d'aucune protection particulière. On propose de classer cette espèce, d'une grande beauté parmi les poissons du Canada, comme vulnérable donné étant le nombre peu élevé d'individus et leur distribution exrêmement limitée.

Key Words: Orangespotted Sunfish, *Lepomis humilis*, crapet menu, Centrarchidae, sunfishes, Ontario, rare and endangered fishes, distribution, population size and trends, range expansion, ecology, habitat, reproduction, life history, status, Canada.

The Orangespotted Sunfish, *Lepomis humilis* (Girard 1858), has only recently been described in Canada (Holm and Coker 1981). Some evidence (Noltie and Beletz 1984) suggests that these populations have arisen in southwestern Ontario through a direct range extension northwards out of Ohio. Since the present Canadian distribution is extremely restricted, and populations exist in low numbers in an area subject to intensive agriculture, this report was commissioned to bring the species to the attention of COSEWIC. Given the species' novelty and the fact that some morphological distinctions exist between populations in the United States and Canada (Holm and Coker 1981), a detailed description is provided.

Description

The Orangespotted Sunfish is one of the most brilliantly coloured of the *Lepomis* species (Eddy and Underhill 1974). Specimens (Figure 1) are moderately deep and compressed to somewhat oblong in shape (Bollman 1892; Hay 1894; Jordan and Evermann 1902; Forbes and Richardson 1920; Cross 1967; Becker 1983) and of rather slender build (Eddy and Underhill 1974). Each possesses relatively high dorsal spines and a long, broad opercular flap (Jordan and Evermann 1902) which is flexible (Richardson 1904; Eddy and Surber 1947; Holm and Coker 1981). The conspicuous black patch this flap bears has a coloured margin varying from white (Harlan and Speaker 1956; Moore 1957;

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

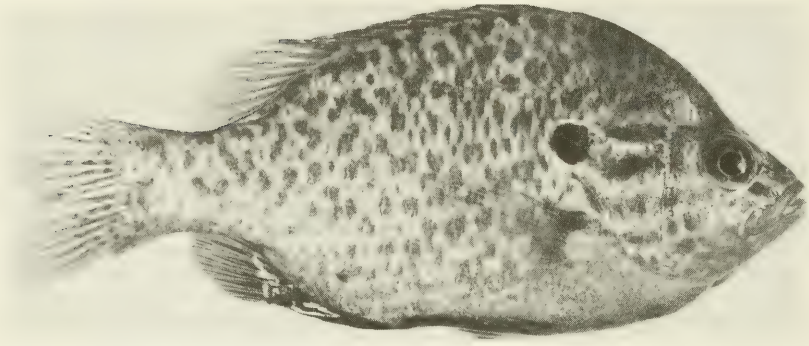

FIGURE 1. Orangespotted Sunfish, *Lepomis humilis*, from Canard River, Ontario, June 1983 (from Noltie and Beletz 1984).

Cross 1967; Miller and Robison 1973; Buss 1974; Pflieger 1975; McClane 1978; Becker 1983) to greyish white (Barney and Anson 1923), white with an occasional flush of orange (Trautman 1981), pale with tinges of red or orange (Eddy and Surber 1947; Eddy and Underhill 1974), wide and pale lavender, pinkish or light crimson (Richardson 1904; Forbes and Richardson 1920), to broad and red, pinkish or orange (Thompson and Hunt 1930; Eddy 1957; Clay 1962) or broad and red, entirely surrounding the black (Hay 1894; Jordan and Evermann 1896, 1904). The mouth is large, the posterior of the maxillary extending beyond the anterior orbit rim (Girard 1858; Moore 1957; Cross and Collins 1975). The scales of the throat are much smaller than those on the flanks (Clay 1962). The morphology of their pharyngeal bones and teeth has been outlined by Richardson (1904).

Typical body colour is olive to bluish, with gold to green spots or mottlings posteriorly (Hay 1894; Jordan and Evermann 1896, 1902; Richardson 1904; Forbes and Richardson 1920; Harlan and Speaker 1956; Cross 1967). The sides and back are greenish with silver-blue reflections, and the belly is white or yellow (Pflieger 1975; Becker 1983), or orange to red as are the lower fins (Bollman 1892; Hay 1894; Jordan and Evermann 1896, 1902; Forbes and Richardson 1920; Eddy and Underhill 1974). The anal fin has a dusky distal margin (Forbes and Richardson 1920). Often a faint black dot occurs on the last rays of the dorsal fin (Jordan and Evermann 1896). The cheeks and opercules possess longitudinal radiating brown, rusty orange, orange, golden, red or emerald streaks (Forbes and Richardson 1920; Barney and Anson 1923; Thompson and Hunt 1930; Eddy and Surber 1947; Clay 1962; Eddy and Underhill 1974; McClane 1978). Bright red, salmon-red, or orange spots numbering 20 to 30 are scattered irregularly over the sides of males, but those on females are brown (Hay 1894; Jordan and Evermann 1896, 1902; Forbes and Richardson 1920; Harlan and Speaker 1956; Clay 1962; Buss 1974; Eddy and Underhill 1974; McClane 1978; Holm and Coker 1981). As such, the Orangespotted Sunfish is one of the few sexually dichromatic centrarchids (Becker 1983; Petersen et al. 1986), colour differences alone being used to sex individuals with 95% accuracy (Petersen 1979; Petersen et al. 1986).

In colouration, non-breeding males are generally silvery with darker backs and whitish bellies (Miller 1963; Trautman 1981). During breeding, the males become more vividly coloured, taking on a pattern more complicated than in most sunfishes (Breder 1936), and thereby differentiating the sexes (Breder and Rosen 1966). A breeding male is opalescent green with the sides of the head iridescent pale-blue streaked by bright orange, the breast and belly orange or red, the fins brilliantly orange, the dorsal fin rays tipped with crimson, the pelvics and anal outlined by black, and the irises red or orange (Barney and Anson 1923; Cook 1959; Cross 1967; Miller and Robison 1973; Trautman 1981; Becker 1983). The belly and lower fins deepen in colour also (Harlan and Speaker 1956). The dorsal in males may possess a narrow edging of crimson anteriorly and a wide margin of white or orange posteriorly (Forbes and Richardson 1920; Harlan and Speaker 1956; Clay 1962). Cook (1959) states that the opercular flap in males is broadly outlined in orange while in females the margin is white. Females are not as brilliantly coloured as males, their body colour tending towards olivaceous green, the flank spots being more dusky, the opercular spot being less contrasting and the fins transparent (Barney and Anson 1923; Becker 1983). As such, they more closely resemble immature males. The colouration of immatures is more subdued, and often includes rather distinct vertical bars and the lack of brownish spotting on the sides (Barney and Anson 1923; Pflieger 1975). Immatures are said to closely resemble Bluegill, *Lepomis macrochirus* (Smith

1979). Because of this, Canadian specimens may have previously gone unnoticed.

Morphologically, the sexes also differ in outline, the angle between the skull and the dorsal profile at the nape being greater in males, yielding a more concave forehead than in females (Forbes and Richardson 1920). As such, reproductively active males were described as "high" by Cross (1950). Males also have longer ventral fins than do females (Forbes and Richardson 1920).

Orangespotted Sunfish are peculiar among centrarchids in that they possess extremely large, slit-like preopercular sensory pores within the lateral line canals of the head (Moore 1957; Curd 1959; Branson and Moore 1962; Cross 1967; Becker 1983), the cranial and facial bones having been called "cavernous" by Ortenburger and Hubbs (1927). The two sensory pit depressions in the skull between the eyes are the largest among the sunfish, their widths being about equal to the distance between them (Pflieger 1975; Becker 1983). Also prominent are the openings along the free edge of the preopercule (Smith 1979; Trautman 1981; Becker 1983). These openings are much larger than the more rounded ones occurring in other centrarchids, their greater size possibly allowing improved detection of pressure waves in the obscured visual environment which prevails in the turbid waters of their typical habitats (Miller and Robison 1973).

Morphologically, Canadian populations appear to deviate in some regards from southern ones. Holm and Coker (1981) provide fin ray counts for two Ontario capture locations, finding their numbers greater than in Kansas specimens examined by Cross (1967). Further counts of this kind (Jordan and Evermann 1902; Forbes and Richardson 1920; Eddy and Surber 1947; Cook 1959; Eddy and Underhill 1974; Pflieger 1975; Becker 1983) also bear out this trend. These differences may be evidence that Canadian populations arose long ago and have since reproduced in isolation. Formal studies of meristic and morphological variation across the species' range would provide a useful test of this possibility.

Distribution

The Orangespotted Sunfish is endemic to North America, its distribution being restricted almost

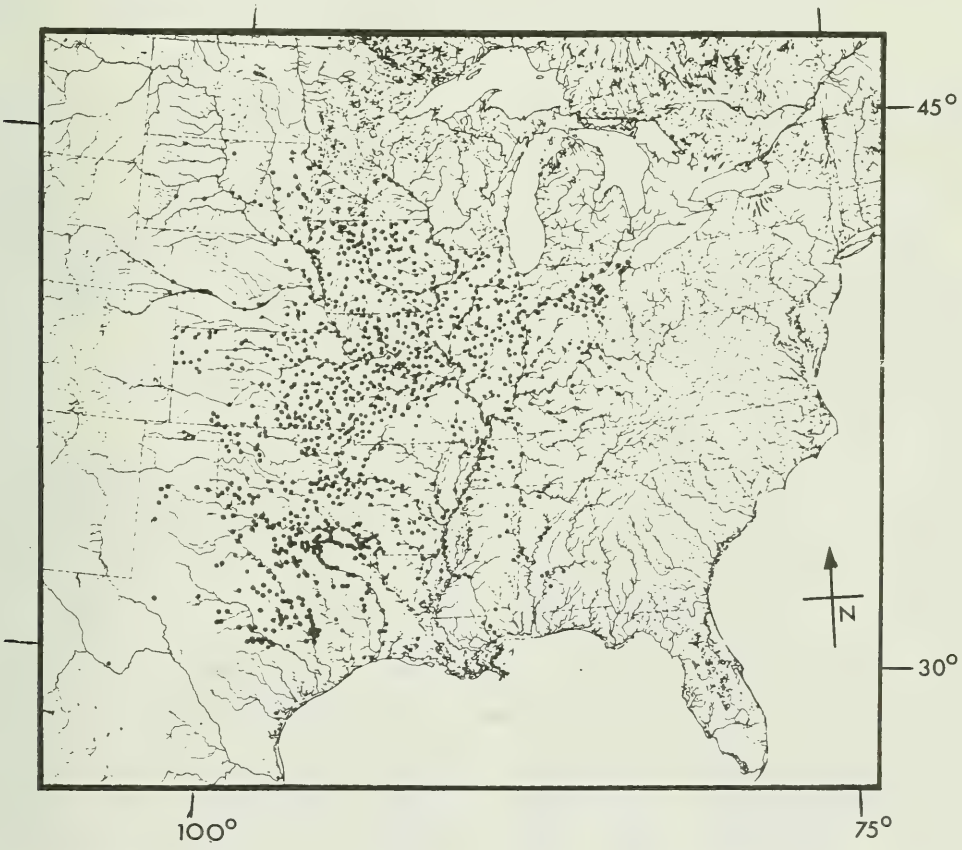

FIGURE 2. North American distribution of Lepomis humilis (adapted from Lee 1980).

exclusively to the east-central United States, primarily in the Mississippi Valley (Figure 2). Its range extends north from Texas through Oklahoma, Colorado and the Dakotas, then east through southern Minnesota, the extreme southern portion of Wisconsin, Illinois and Indiana to western Ohio, and then south through Kentucky, Tennessee and Alabama. Within these boundaries, its distribution is continuous. However, it is most abundant in the west and southwest of its range (Hay 1894). Greene (1935) suggests that it underwent little post-glacial dispersal. Distribution details are provided elsewhere (Hay 1894; Meek 1895; Jordan and Evermann 1896, 1902; Forbes and Richardson 1920; Barney and Anson 1923; Greene 1935; Gerking 1945; Eddy and Surber 1947; Moore and Buck 1953; Eddy 1957; Moore 1957; Hubbs and Lagler 1958; Cook 1959; Bailey and Allum 1962; Clay 1962; Nelson and Gerking 1968; Smith-Vaniz 1968; Pflieger 1971, 1975; Miller and Robison 1973; Buss 1974; Eddy and Underhill 1974; Cross and Collins 1975; McClane 1978; Smith 1979; Lee 1980; Trautman 1981; Becker 1983; Cooper 1983).

Trautman (1981) concluded that the species' native range was restricted to the Mississippi drainage and hypothesized that this confinement was first broken around 1929 when specimens were discovered in Ohio's Lake St. Marys (the lake divides the Wabash/Ohio/Mississippi system and the St. Marys/Maumee/Lake Erie drainage). Trautman (1981) speculated that their presence in Lake St. Marys may have resulted from human activity, some individuals having been transported over the levee/spillway at its western end. According to Trautman (1981) the species then expanded westwards, Portage River and Sandusky River specimens being taken in 1949. Immediately north of the mouths of these rivers lies Ohio's Bass Island chain, and specimens were taken there from South Bass Island in 1952. White et al. (1975) reported finding Orangespotted Sunfish in a Lake Erie tributary near Cleveland, Ohio, in 1971-72 and Trautman (1981) considered this a significant eastward extension of the range in Ohio.

In contrast to the invasion scenario above, several lines of evidence point to Orangespotted Sunfish being native to the Lake Erie basin. Hubbs and Brown (1929) provide evidence of the species' presence in the Lake Erie basin upstream of Niagara Falls at a date earlier than the 1929 invasion suggested by Trautman (1981). Nelson and Gerking (1968) considered the species to be a native of Indiana found in all major drainages (including Erie's) except those of Lake Michigan. Emery (1976) also included the species among inhabitants of Lake Erie in the United States based on examination of unpublished commercial catch records, research vessel cruise reports, power plant entrainment studies and Great Lakes Fishery Commission reports, and classified the species as being uncommon in the lake but in stable populations. Likewise, Hocutt and Wiley (1986) suggested that these fish are native to tributaries of Lake Erie.

In addition, Gerking (1945) states that Orangespotted Sunfish were widely distributed in Indiana's downstream portion of the Maumee River as of 1945, whereas Trautman (1981) suggests that the species only became established in the upstream portion of the Maumee in Ohio after 1929. Together, one might interpret these two reports as indicating a rapid and extensive invasion of the Maumee system. However, this seems unlikely given the time elapsed, suggesting instead that Orangespotted Sunfish were native to the Maumee and thus to the Lake Erie watershed.

Finally, Wise (1980) reported 1963 finds of Orangespotted Sunfish in Racoon Creek, a tributary of Ohio's Licking/Muskingum River system which empties into Lake Erie at Lorain via the Black/Kilbuck rivers. This evidence of the occurrence of Orangespotted Sunfish in eastern Ohio is significant in that it predates White et al.'s (1975) report from near Cleveland which Trautman (1981) used in postulating his range extension scenario. Instead, this early eastern Ohio find lends further support to the species being native to tributaries of Lake Erie.

Despite the above, the species' presence in Canada probably does reflect some northward range expansion. Given its uncommon occurrence in Lake Erie (Emery 1976) it is not surprising that the species has only recently been discovered in Canadian waters. It may have existed in the latter for some time, as morphological differences have been noted (Holm and Coker 1981) between Canadian and United States populations.

In Canada, populations of Orangespotted Sunfish have been discovered at six different southwestern Ontario localities (Table 1, Figure 3). The most southerly, from Pelee Island (Table 1), occurs ca. 24 km northeast of South Bass Island. Cedar Creek, on the Lake Erie north shore ca. 25 km north of Pelee Island, has produced specimens from four locations at various points along its lower reaches (Table 1). By their abundance here, these populations are apparently well-established (Holm and Coker 1981). A sixth site, Canada's most northern to date, occurs on the Canard River ca. 10 km north of the Cedar Creek site furthest upstream. Noltie and Beletz (1984) provide evidence that it too supports a reproducing population. These Canadian populations may only be of localized abundance, since extensive Ontario Ministry of Natural Resources (OMNR) and National Museums of Canada (NMC; now Canadian Museum of Nature) surveys conducted in 1979 and 1980 in the

TABLE 1. Captures of Orangespotted Sunfish (*Lepomis humilus*) made in Canada to date. ROM = Royal Ontario Museum voucher specimen holdings. NMC = National Museums of Canada, Museum of Natural Sciences voucher-specimen holdings.

Collection	Capture Date	Latitude	Longitude	Number Caught	Location
ROM 45577	15/05/84	41°48′42″N	82°39′31″W	—	inside eastern breakwater, North Bay, Pelee Island, near Scudder
NMC 85-0529	14/07/83	42°01′00″N	82°47′00″W	2	Cedar Creek mouth at Lake Erie, Gosfield South Township, Essex County
NMC 81-0055	11/06/80	42°01′30″N	82°49′18″W	8	Cedar Creek, 0.5 km S of Arner, Colchester South and Gosfield South Townships, Essex County
ROM 36442	11/06/80	42°01′38″N	82°49′27″W	38*	Cedar Creek, Colchester South Township, Essex County
ROM 36441	11/06/80	42°01′53″N	82°49′53″W	38*	Cedar Creek, W of Arner, Colchester South Township, Essex County
Noltie & Beletz (1984)	21&23/06/83	42°07′24″N	82°50′51″W	8	Canard River, 3 km SW of Gesto, Colchester North Township, Essex County

*indicates two collections whose catch together totalled this number.

immediate vicinity of these capture locations failed to locate *Lepomis humilis* specimens (G. Duckworth, OMNR Chatham, Ontario; personal communication). Canadian Orangespotted Sunfish habitat may also differ seasonally, the populations sampled on 11 June 1980 by Holm and Coker (1981) having been resampled by me on 15 July 1981 without success. Failure to encounter *Lepomis humilis* populations elsewhere in the Lake Erie and Ontario watersheds, despite widespread and vigorous sampling by the OMNR, suggests that the restricted range indicated in Table 1 is relatively accurate.

Protection

The Orangespotted Sunfish is not specifically protected in Canada. Provisions of the federal Fisheries Act offer some general protection from potential habitat degradation, as do provincial and municipal statutes of this nature. Ontario fishing regulations permit the taking of this species year round. No size or possession limits apply.

Population Sizes and Trends

Estimates of population sizes and trends have not been established for the Orangespotted Sunfish in Canada. Although present populations appear small and narrowly distributed, trends in abundance and distribution elsewhere (*see* below) suggest that their range and numbers in Canada are likely to continue growing.

Several reports propose that man has acted directly to increase the species' distribution. A more widespread occurrence in South Dakota west of the Missouri River suggests that inadvertent plantings with other species have occurred (Bailey and Allum 1962). Smith-Vaniz (1968) states that their presence in coastal drainage areas of Alabama east of the Mississippi and in a Georgia pond have similarly resulted from recent plantings. Captures have been made in a stocked Colorado reservoir (Gregory et al. 1979; Powell 1972, 1973). Farm pond introductions have extended its range within Ohio also (Trautman 1981). Thus, Lee (1980) contends that the general eastern and western spread of the species has resulted from unintentional introductions.

Habitat alteration has also favoured range expansion in this species. More widespread distributions in Indiana have accompanied agricultural practices which transformed clear prairie-type streams to turbid plains-type ones (Gerking 1945). Buth (1974) and Smith (1979) found the species more abundant and widespread after long-term increases in siltation in Illinois. Trautman (1981) relates the invasion of the species into central Ohio to increased stream turbidity and siltation of stream bottoms caused by clearing and tilling. Population sizes increased when small Ohio streams were channelized (Carline and Klosiewski 1985). Greater centrarchid abundance, with *Lepomis humilis* comprising a large portion, also resulted

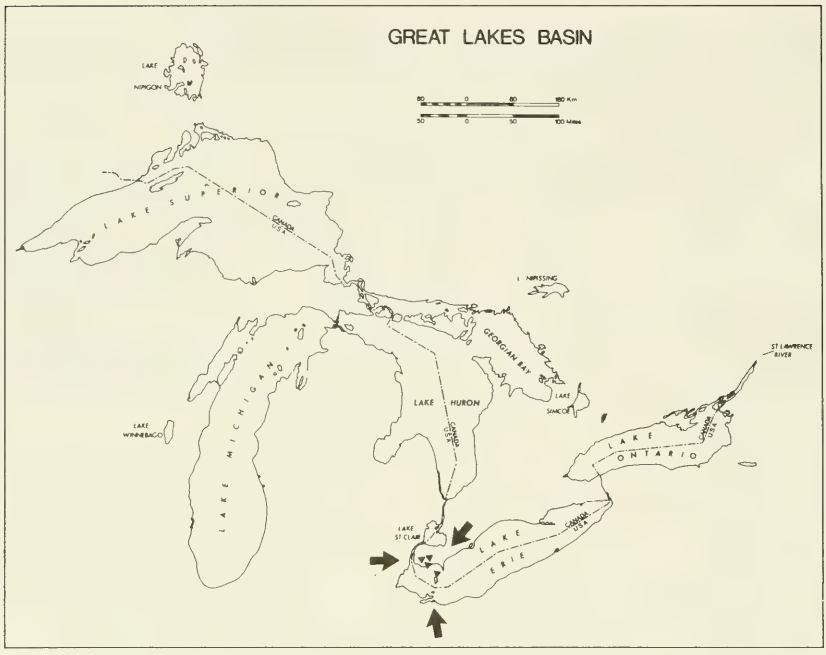

FIGURE 3. Canadian (Ontario) distribution of the Orangespotted Sunfish.

from installing floating tire breakwaters in an Oklahoma reservoir (Clady et al. 1979). Similar habitat changes may be expected to favour Canadian populations.

In contrast, human influences have also affected some populations adversely. Larimore and Smith (1963) report that the species' abundance and distribution shrank in parts of Illinois with stream changes caused by man. In Kansas, the species' distribution also failed to increase despite lake construction and stocking programs (Cross 1967). Populations have declined in areas of preferred habitat in Illinois, despite changes tending to produce more habitat apparently favourable to the species (Smith 1968). Reduced abundance in Illinois has accompanied draining of the prairie wetlands (Smith 1979). Isolation from a feeder stream, dredging, and stocking with Pike (*Esox lucius*) and Largemouth Bass (*Micropterus salmoides*) completely decimated one Iowa pond population (Carlander 1978). In Colorado, changes since European settlement have caused the species' range in the South Platte system to shrink sufficiently for it to be designated rare (Propst and Carlson 1986), although in none of the American states are populations considered threatened (Miller 1972; Johnson 1987). Obviously, large-scale habitat changes like those above are likely to impact negatively on Canadian populations.

Habitat

Many authors provide information on the general habitat preference of the Orangespotted Sunfish. In the lower Missouri River basin, the species was said to reach local abundance in sandy streams (Jordan and Evermann 1902). Tolerance of a wide range in pH, and rapid changes thereof was shown by Wiebe (1931), who observed spawning in waters as high as pH 9.3. Inhabitation of turbid waters in the Great Plains region may have been responsible for the evolution of the species' large lateral line canals (Moore 1956). Orangespotted Sunfish reportedly frequent turbid lentic, and sluggish lotic waters, often to the exclusion of other sunfishes (Branson and Moore 1962). Miller (1963) considered the species tolerant of mud and silt in ponds and streams. Where it occurs outside of Great Plains areas, stream habitats resembling those of the Plains are chosen (Metcalf 1966). Lee (1980) describes its habitat as being quiet streams and vegetated lakes or ponds. Cooper (1983) lists it as an inhabitant of turbid, silty streams and ponds. Hocutt and Wiley (1986: 169) list the species as a dweller in both upland and lowland streams and big rivers.

Despite the generalizations above, Orangespotted Sunfish habitat varies considerably throughout the range. An effort has been made to draw together the literature pertaining to this subject and a summary is presented in Table 2. Since co-occurring species are also important components

TABLE 2. Summary of literature references dealing with the habitat preferences of *Lepomis humilis*, and their species associates age and growth rates.

Area	Habitat	Species Associates	Age & Growth
Alabama	Tarzwell (1945)	Tarzwell (1945), Alabama Department of Conservation (1958), Smith-Vaniz (1968)	Swingle (1965)
Colorado	Powell (1973), Propst and Carlson (1986)	Barnhart 1955	Barnhart 1955, Gregory et al. (1970), Powell (1972, 1973)
Illinois	Forbes and Richardson (1920), Thompson and Hunt (1930), O'Donnell (1935), Brown and Thompson (1937), Whitacre (1952), Stegman (1958, 1959), Larimore and Smith (1963), Smith (1968, 1979)	Forbes and Richardson (1920), Cahn (1927), Bennett (1943), Upper Mississippi River Conservation Commission* (1948a), Stegman (1958, 1959), Lopinot (1967, 1968), Buth (1974)	Whitacre (1952), Lopinot (1958), Stegman (1958), Starrett and Fritz (1965)
Indiana	Gerking (1945)	Whitaker et al. (1977)	—
Iowa	Meek (1895), Barney and Anson (1923),Harlan and Speaker (1956), Mitchell et al. (1980)	Meek (1985) UMRCC (1948a)	Barney and Anson (1923), Carlander (1949), Carlander and Parsons (1949), Carlander and Parsons (1949), Harlan and Speaker (1956)
Kansas	Cross (1954, 1967), Minckley (1956, 1959), Prophet (1957), Metcalf (1959, 1966), Deacon (1961), Deacon and Metcalf (1961), Gash (1967), Gash and Gash (1973), Cross and Collins (1975)	Moore and Buck (1953), Minckley (1956, 1959), Schelske (1957), Metcalf (1949, 1966), Cross (1954, 1967), Deacon and Metcalf (1961), Gash (1967), Gash and Gash (1973)	Minckley (1959)
Kentucky	Carter (1954), Clay (1962)	Carter (1954)	
Louisiana	Barney and Anson (1923), Carver (1967)	Barney and Anson (1923)	Barney and Anson (1923), Carver (1967)
Minnesota	Eddy and Surber (1947), Eddy and Underhill (1974)		—
Mississippi	Cook (1959), Font et al. (1984)	—	Cook (1959)
Missouri	Pflieger (1971, 1975)	—	—
Nebraska	Meek (1895), Canfield and Wiebe (1931)	—	—
Ohio	Wise (1980), Trautman (1981)	Clark (1960), Hoke et al. (1979), Laskowski-Hoke et al. (1982), Carline and Klosiewski (1985)	Clark (1960), Trautman (1981)
Oklahoma	Moore and Paden (1950), Cross and Moore (1952), Ward (1953), Finnell (1954), Elkin (1955), Jenkins et al. (1955), Gould and Irwin (1965), Branson (1967), Bross (1969), Miller and Robison (1973), Margraf and Plitt (1982)	Hubbs and Ortenburger (1929), Cross (1950), Moore and Paden (1950), Thompson (1950), Buck and Cross (1951), Cross and Moore (1952), Moore and Buck (1953), Branson (1967), Orth (1980)	Cross (1950), Buck and Cross (1951), Jenkins (1953), Finnell (1954), Elkin (1955), Jenkins et al. (1955), Jenkins and Finnell (1957), Gould and Irwin (1965), Whiteside (1967), Whiteside and Carter (1973)
South Dakota		Shields (1955), Bailey and Hubbs (1962), Wahl and Applegate (1981)	Shields (1955)
Wisconsin	Greene (1935), UMRCC (1948b), Christenson and Smith (1965), Becker (1983)	Cahn (1927), UMRCC* (1948b), Christenson (1957), Christian and Smith (1965)	Meehean (1932), Christenson (1957), Christenson and Smith (1965), Becker (1983)

*UMRCC = Upper Mississippi River Conservation Commission.

of habitats, studies documenting these are also noted.

In Canada, the Cedar Creek populations (Table 1) were found in shallow muddy waters with bottoms of silt, clay and detritus (Holm and Coker 1981). Canard River specimens came from like habitat, the sample site being shallow, slow-flowing, turbid, and free of aquatic macrophytes, with a primarily clay-silt bottom (Noltie and Beletz 1984). Species co-occurring there were similar to many of the species suites referred to elsewhere (Table 2) for American populations. As such, Canadian populations seem to have maintained the general habitat preferences they exhibit in the United States. The Lake Erie population at Pelee Island is somewhat anomalous, however, since large lakes appear to be rarely inhabited by this species.

General Biology

Age and Growth: Orangespotted Sunfish are usually said to reach 9 to 10 cm in length (Jordan and Evermann 1896, 1902; Richardson 1904; Forbes and Richardson 1920; Eddy and Surber 1947; Ward 1953; Eddy 1957; Clay 1962; Cross 1967; Buss 1974; Eddy and Underhill 1974; Cross and Collins 1975; McClane 1978). Lengths of 5 to 7.5 cm are more typical (Hay 1894; Eddy and Underhill 1974), but individuals 12 to 16 cm long have also been recorded (Barnhart 1955; Jenkins et al. 1955; Lopinot 1958; Swingle 1965; Carver 1967), these being considered exceptional. Seven years is the maximum recorded age, although individuals in most populations fail to live past their fourth year, and growth is not slowed initially by the attainment of sexual maturity (Barney and Anson 1923). Some Oklahoma reservoir populations are apparently annuals (Jenkins 1953; Finnell 1954; Elkin 1955). Carlander (1977) provides a summary of growth and condition in the species. Recorded standing crop estimates for the species are also summarized by Carlander (1955) and Whiteside and Carter (1973). Various studies of age and growth in this species have been conducted, and the references are summarized in Table 2 by state. These indicate that the lifespan of southern individuals is often shorter than in the north, and that maturity at age classes II and III is more typical. Southern specimens generally grow more rapidly, due likely to the longer feeding and growing seasons and earlier breeding period. Growth occurs primarily in late spring and early summer (Barney and Anson 1923; Jenkins et al. 1955; Shields 1955). Trautman (1981) and Becker (1983) document the sizes of young of the years in Ohio and Wisconsin, respectively.

In Canada, only two populations have been sampled for age and growth. Cedar Creek individuals ranged between 36 and 97 mm total length (TL). Females of 51 to 58 mm TL were gravid, and the two largest males (83 and 97 mm TL) were older males with enlarged ear flaps. Smaller specimens there were males and/or juveniles (Holm and Coker 1981). Canard River specimens ranged from 45 to 107 mm TL and age classes II to IV, males being the largest among the collected specimens. A length-weight regression for this sample was calculated by Noltie and Beletz (1984). Together, data from these two studies indicate that Canadian *Lepomis humilis* are of sizes and occur in populations with age structures similar to those described from elsewhere in the range.

Diet: Information on the diet of Canadian Orangespotted Sunfish does not exist. However, food studies have been made on natural populations from further south (Barney and Anson 1923; Cahn 1927; Hildebrand and Towers 1927; Rice 1941; Lagler and Ricker 1942; Clark 1943; Harrison 1950; Ward 1953; Kutkuhn 1955; Stegman 1958, 1959; Wenke 1965; Whitaker 1975; Gaudet personal communication: *in* Becker 1983). These indicate that aquatic insects at various life stages and crustaceans compose most of the diet. Midges, mayflies, caddis flies and water boatmen dominate the aquatic insect component, while amphipods, cladocera, copepods, isopods and ostracods constitute the crustacean portion. Water mites, bryozoans, small fish, and plant material are also important. Kutkuhn's (1955) analysis of specimens from a dredged lake indicated that the insects consumed originate primarily in shallow water. Clark (1943) makes a similar conclusion based on diet studies from other lake specimens. Cross and Collins (1975) also consider their diet in Kansas to be mostly insects. The species' long, pointed and slender gill rakers likely facilitate taking such foods (Jordan and Evermann 1902; Forbes and Richardson 1920; Eddy and Surber 1947; Eddy 1957; Clay 1962; Cross 1967; Eddy and Underhill 1974). Larger food items tend to be consumed as individuals surpass the yearling stage (Kutkuhn 1955). Larger *Lepomis humilis* also eat smaller ones on occasion (Barney and Anson 1923; Lagler and Ricker 1942). The species has been classified as one having a food chain of intermediate length (Carlander 1955). Intraspecific competition for such food resources can be intense, large year classes decreasing in mean weight per individual (Orth 1980).

In the laboratory, various aquarium studies indicate that specimens fare well on diets of daphnia and other live foods (Luce 1938; Harlan and Speaker 1956), live *Daphnia magna* (Gould and Irwin 1965), or dried commercial flake food, *Daphnia, Chironomus* larvae, and earthworms (Dennis 1970; Powell 1972).

Behaviour: Miller (1963) and Miller and Robison (1973) considered the Orangespotted Sunfish more gregarious than other *Lepomis* species such as the Green Sunfish. Their feeding was described as voracious by both Branson and Moore (1962) and Gould and Irwin (1965). Although pugnacious (Branson and Moore 1962), nesting males may frighten sufficiently to temporarily vacate their nests (Cross 1967). Miller's (1963) classic work describes comfort movements, and feeding, sleep, locomotory, agonistic, social, nesting, courtship and spawning behaviours in the species. Captive specimens adapt easily to holding conditions (Gould 1962; Gould and Irwin 1965; Irwin 1965), although Miller (1963) found them difficult to acclimatize and the species quite timid. Aspects of their agonistic behaviour and social organization have been examined in the laboratory (Dennis 1970; Powell 1972; Petersen 1979), common behaviours including approach, fin erection, bite, chase, opercular spread, tail beat, and avoid. Behavioural changes among males, primarily decreased levels of aggression, have been used effectively in bioassay work examining the sublethal effects of wastewaters (Shelford 1917; Petersen 1979; Petersen et al. 1986). Changes in iris colouration, ability to retain equilibrium, feeding habits, exaggerated breathing movements, and irritability were also observed (Petersen 1979). There is some indication that individuals are more active in summer months than in winter (Petersen 1979).

Reproduction: Little is known of the breeding biology of Orangespotted Sunfish in Canadian populations. Holm and Coker (1981) report that Cedar Creek females were gravid 11 June. Noltie and Beletz (1984) found sexually mature Canard River males of ages two through four years to have been greater than 55 mm TL. These had free-flowing milt when caught on 21 and 23 June 1983. No further information on Canadian populations exists.

In southern populations, reproductive maturity is reached relatively early in life. Breeding must occur in the first year of life in the single age class populations reported from Oklahoma (Jenkins 1953; Finnell 1954; Elkin 1955). Barney and Anson (1923) found that some *Lepomis humilis* young matured in their second year, but that the majority laid their first eggs at the beginning of their third year. The smallest gravid female they measured was only 3 cm in length. Cook (1950) stated that Mississippi individuals often spawn when only 6 cm long, while the smallest reproductive individual in Whitacre's (1952) Illinois lake population was 37 mm standard length (SL). Lee's (1980) statement that a minimum size of 48 mm is required for reproductive maturity thus appears in error.

Information on the breeding season of the Orangespotted Sunfish is scattered and fragmentary. The following information is arranged in order of increasing latitude. In Louisiana, spawning begins in early April and continues until September, the critical onset temperature being 18° C (Barney and Anson 1923). Well-developed young are seen as early as late April. In Mississippi, Hildebrand and Towers (1927) captured ripe specimens between June and September. In Oklahoma, breeding individuals were found in late May when temperatures reached 25° C, and young-of-the-year were taken by early July at 28° C (Cross 1950). The height of the spawning season is thus in early spring in Oklahoma, but may extend to July or August (Ward 1953). Brood stock seeded in an Oklahoma pond in May spawned and produced seinable offspring by August of the same year (Gould and Irwin 1965). In Kansas, nesting was observed in late June and early July (Minckley 1959). The peak in spawning activity occurs in Kansas in late May and June, water temperatures spanning 24° to 32° C (Cross 1967), In Missouri, Pflieger (1975) states that nesting occurs from late May into August. In Illinois, males and females in breeding colour were observed over new nests in late May in a marsh. Gravid females and brightly coloured males were seen as late as early July in an adjacent lake (Richardson 1913). Pairs of ripe males and females in breeding colouration were found in Illinois in early June (Forbes and Richardson 1920). Cahn (1927) captured an Illinois male in full breeding colouration in early July. Young-of-the-year were taken in the latter part of June by Whitacre (1952). Gonad examinations also confirm a May and early June spawning season in Illinois (Stegman 1958, 1959). In Iowa, breeding begins in late May and ends in August (Barney and Anson 1923; Harlan and Speaker 1969). In Wisconsin, spawning takes place from May to July (Eddy and Surber 1947). Becker (1983) found that spawning occurred in Wisconsin from late May to August, beginning at water temperatures of about 18° C and continuing to 24° to 32° C. Lee (1980) suggests that nesting occurs from May to July in northern portions of the range, and from April to September in the south. The peak spawning period occurs in late April or early May, although stragglers extend this to early August (McClane 1978). Younger fish nest later in the season and geographical location and weather conditions also modify season length (Barney and Anson 1923).

Orangespotted Sunfish are classified among the nest-spawning lithophilic fishes which guard their young (Balon 1975; Orth 1980). Males construct the nests (Buss 1974) which are roughly circular, are 3 to 4 cm deep, and are excavated by the males

either pushing or sweeping the substrate into position (Barney and Anson 1923). As this sweeping motion occurs, males move from a horizontal to a vertical, head-up position, making little horizontal movement through the nest (Miller 1963; Keenleyside 1979). Nests are situated where sand or fine gravel can be exposed (Cross 1967; Buss 1974), or are dug through mud and silt until solid bottoms of gravel are reached (Barney and Anson 1923). Branson (1967) suggests that nests may also be constructed in rocks and gravel. Where only a mud bottom occurred, Louisiana males constructed no distinct nests (Barney and Anson 1923).

Nests have been observed at depths of 46 cm in an Illinois marsh by Richardson (1913), at depths of 30 to 91 cm in Iowa where they were placed in areas of soft bottom and measured 15 to 18 cm in diameter (Barney and Anson 1923), and in water depths from 10 to 61 cm in Kansas (Cross 1967). Thus, nests are generally in water less than 90 cm deep, although occasionally spawning occurs at depths just sufficient to cover the backs of the spawners (McClane 1978).

Males typically nest in clusters, the maximum recorded size apparently being a colony of nearly 1000 which formed a band about a metre wide along a ca. 110 m bank in Iowa (Barney and Anson 1923). Within these colonies, males defend individual territories 30 to 60 cm in diameter (Cross 1967).

Barney and Anson's (1923) study of reproduction is the most complete to date, and yields the following information. After completing his nest, a male attracts a female to it. Spawning then occurs in typical centrarchid fashion, the pair adopting a parallel position over the nest, whereupon eggs and sperm are released. The female then departs. The mating system is one of promiscuous polygamy. Males guard the eggs, which measure 1 mm in diameter and are adhesive. Fanning of the eggs by the parental male prevents siltation. Males also defend the nest territory aggressively. Darters, minnows, and adjacent males all prey on the nest contents. The egg stage lasts about five days at water temperatures of 18° to 21°C. Newly hatched young are 1 cm in length. Females contain up to 4700 eggs, fecundity varying with size and progress through the breeding season (Barney and Anson 1923).

Hildebrand and Towers (1927) report that one 60 mm female contained nearly 1200 ripe eggs, double the number contained by two others of nearly the same length. A 10.8 cm female from Oklahoma bore about 5000 eggs (Ward 1953). Eddy and Surber (1943: *in* Breder and Rosen 1966) reported 15 000 to 58 000 eggs per fish in Wisconsin females, a figure which is not repeated in a subsequent edition of this book. Further information on fecundity is provided for Colorado females by Beckman (1952), and for Wisconsin females by Becker (1983). Only 25 to 300 of these eggs are laid through a spawning bout (Buss 1974; McClane 1978), these being deposited in numbers of between 5 to 15 on each tilt of the male and female (Miller 1963). The eggs are minute and nearly colourless, appearing as grains of clear quartz sand, and adhere to the nest substrate (Cross 1967). The adhesive, amber-coloured eggs produced by Wisconsin females measured 0.5 mm in diameter (Becker 1983). Minnows are acknowledged egg predators, and swarm into temporarily deserted nests (Cross 1967).

The young and their pigmentation are described in Auer (1982), yolk-sac larvae measuring 5.3 mm TL, larvae 7.9 mm TL. Red Shiners (*Notropis lutrensis*) and Redfin Shiners (*Notropis umbratilis*) have been known to spawn over nests of this species in Missouri (Pflieger 1975). The grunting sounds used by *Lepomis humilis* males to attract conspecifics during courtship and how these sounds differ from those of other *Lepomis* species are documented by Gerald (1971).

Hybridization: Hybrids frequently occur between Orangespotted Sunfish and Bluegill (O'Donnell 1935; Luce 1938; Cross and Moore 1952; Stegman 1958; Breder and Rosen 1966; Branson 1967; Mitchell et al. 1980), Green Sunfish (Hubbs and Ortenburger 1929; Hubbs and Hubbs 1933; Breder 1936; Luce 1938; Minckley 1959; Bailey and Allum 1962; Zach 1968; Bross 1969; Trautman 1981), Longear Sunfish, *Lepomis megalotis* (O'Donnell 1935; Cross 1950), Pumpkinseed, *Lepomis gibbosus* (O'Donnell 1935; Luce 1938; Upper Mississippi River Conservation Committee 1948b; Trautman 1981), and Redear Sunfish, *Lepomis microlophus* (Trautman 1981), and with the Warmouth, *Lepomis gulosus* (Whitmore 1986). Slastenenko (1957) and Schwartz (1972) list further sources reporting these hybrid combinations. Such hybrids reach greater size then do purebred *L. humilis* specimens (Eddy and Underhill 1974).

This frequent hybridization may occur because Orangespotted Sunfish occasionally breed in areas used by other *Lepomis* species (Minckley 1959; Gerald 1971; Eddy and Underhill 1974), increasing opportunities for inter-specific pair formation. Alternatively, Branson (1967) suggested that such hybrids form because Orangespotted Sunfish are occasionally forced to spawn with congeners with which they become trapped when small, sluggish streams are reduced to intermittent pools for long periods. The use of species-specific courtship sounds (Gerald 1971) may aid in reducing such pairings, however.

Trautman (1981) states that in cases of *Lepomis humilis* range expansion, the leading front is invariably associated with frequent inter-specific hybridization, immigrants in small numbers being forced to mate with members of other species. However, once *Lepomis humilis* populations are well established, hybrids are less frequently encountered. Accordingly, Holm and Coker (1981) found that hybrids with Pumpkinseed constituted more than 10% of their collections from Canadian populations. Trends in hybrid numbers should be watched should Canadian populations prove non-ephemeral.

Parasites: Because of its recent occurrence in Ontario waters, a listing of parasites for Canadian populations is not provided by Margolis and Arthur (1979). Hoffman (1967) supplies a summary of the known parasites of the species across North America, but does not include the following. Coker et al. (1922) report that Orangespotted Sunfish are infected naturally by glochidia of the Yellow Sand Shell, *Lampsilis anodontoides*, a freshwater clam. Cross (1960) reports that in Ohio populations *Lernea carassii* infects the species. McDaniel and Bailey (1966) report that cestodes, nematodes, and various trematodes parasitized *Lepomis humilis* specimens from Oklahoma. Gash (1967) and Gash and Gash (1973) list trematode, cestode, and nematode parasites from Kansas samples, and found greater numbers of some species in larger fish indicating that infection may occur on a cumulative basis. The crustacean *Lernaea cyprinacea* heavily parasitized some specimens in Indiana (Whitaker and Schleuter 1975), and monogenetic trematodes infested *Lepomis humilis* specimens from Oklahoma (Petersen 1979). Crites et al. (1984) found the species infected heavily with Neascus-type trematode metacercaria, and natural metacercarial infections by the parasite *Phagicola nana* occurred in collections from brackish estuaries of the Mississippi Gulf Coast (Font et al. 1984). Larger fish were more heavily infected and the distribution of parasites through the body greater.

Concerning resistance to parasitism, Anson and Howard (*in:* Barney and Anson 1923) state that the species is the only centrarchid which resisted infection by glochidia of the clam *Lampsilis luteola*. The gall bladder parasite *Chloromyxum trijugum* also failed to infect Orangespotted Sunfish or hybrids with Bluegill (Mitchell et al. 1980).

Limiting Factors

Canadian populations of Orangespotted Sunfish may be limited by competition with other small native centrarchids. Competition with crappies (*Pomoxis* sp.), Bluegill and young bass (*Micropterus* sp.) for food was considered likely by Cross (1967). Competition with Green Sunfish was suggested as being partially responsible for the scarcity of Orangespotted Sunfish in Colorado (Propst and Carlson 1986). Because such competing species are widely distributed across southern Ontario, *Lepomis humilis* may be prevented from flourishing. In contrast, however, differences in feeding structures have also been suggested to reduce competition between *Lepomis humilis* and crappies (Forbes and Richardson 1920), and their ability to outcompete Bluegill was expected to herald increased abundance in a polluted Oklahoma stream (Cross 1950).

Predation by other species may also impose limitations on the species in Ontario systems. As outlined later, species of native southern Ontario fishes such as Largemouth Bass and Muskellunge are known predators of Orangespotted Sunfish. These may also mediate *Lepomis humilis'* population growth.

The continued degradation of southern Ontario streams may also limit their spread and numerical increase. Given that the species is a typical inhabitant of turbid waters, continued field draining, stream channelization, and increased siltation and turbidity appear initially favourable to the species. However, Smith (1968) found that even where such changes occurred, *Lepomis humilis* was decimated in Illinois rivers. Limits to which habitat changes benefit the species thus exist.

Concerning pollution, Orangespotted Sunfish were considered the most tolerant of the species in an Oklahoma stream (Cross 1950). In particular, the species' tolerance for oil refinery wastewaters is considered good (Gould 1962; Gould and Irwin 1965; Irwin 1965), perhaps important given the size of southwestern Ontario's petrochemical industry. Despite such resilience, many fractions of oil refinery waste are lethal to Orangespotted Sunfish, especially among smaller individuals (Shelford 1917). Early mortality due to oil pollution was suggested by the findings of Jenkins and Finnell (1957) also. Such exposure alters their agonostic behaviour (Petersen 1979; Petersen et al. 1986), and since territoriality is important during nesting in this species, deleterious effects on breeding populations may be expected. Zinc and cadmium concentrations in a small sample were high relative to a variety of species examined by Murphy et al. (1978), suggesting that the accumulation of environmental contaminants might limit *Lepomis humilis*. Indiviuals also accumulate organochlorine, heavy metal, and other elemental contaminants (Lowe aet al. 1985; Schmitt et al. 1985). Clark (1960) also refers to the occurrence of thyroid hyperplasia in Ohio specimens.

Special Significance of the Species

The Orangespotted Sunfish belongs to the most species rich of the centrarchid genera (Avise and Smith 1977). Historically, the genus *Lepomis* first appears at the Miocene-Pliocene boundary (Miller 1965). Fossil jaw bones of *Lepomis humilis* containing its characteristically enlarged sensory canal pores date the species back approximately 1.2 million years to the early Pleistocene (Bennett 1977; Bennett 1979). Branson and Moore's (1962) consideration of centrarchid lateral line systems provides evidence of the species' taxonomic status within the family, differences in their lateral line pore shape once having been responsible for their placement in the genus *Allotis* (Ortenburger and Hubbs 1927). The congener closest to them is the Bluegill (Bailey 1938; Avise and Smith 1974, 1977; Whitmore 1986), which may explain the similarities in their behaviour (Miller 1963) and the frequency of hybrids between the species (see above). Chromosome numbers and morphology in *Lepomis humilis* suggest that the species is an offshoot of the main centrarchid line (Roberts 1964a). Whereas all other *Lepomis* species have 48 chromosomes (Roberts 1964a), the diploid count in *Lepomis humilis* is 46 (Roberts 1964a,b, 1967; Becker 1983). Existing genetic variability estimates (Avise and Smith 1974, 1977; Avise 1977; Avise et al. 1977) form the basis upon which evidence of founder effects in Canadian populations could be examined.

From an aesthetic standpoint, Orangespotted Sunfish are unique among Ontario's fish species. Spawning males are said to be the most strikingly colourful of all sunfishes (Hay 1894; Jordan and Evermann 1902; Forbes and Richardson 1920; Cahn 1927; Hildebrand and Towers 1927; Eddy and Underhill 1974; Cross and Collins 1975). During the breeding season; "the males are so brilliantly coloured they appear to be more artificial than real" (Harlan and Speaker 1956) and because of this they are attractive as aquarium fishes.

Larger specimens may be occasionally kept when angled (Starrett and Fritz 1965), and are considered a valuable pan fish (Evermann and Cox 1896). They apparently bite readily (Jordan Evermann 1902; Harlan and Speaker 1956), worms and grasshoppers being effective baits (Cross 1967; Eddy and Underhill 1974). Because of their small size, most anglers value them little as sport fish (Hay 1894; Jordan and Evermann 1902; Jenkins et al. 1955; Harlan and Speaker 1956; Cross 1967; Buss 1974; Eddy and Underhill 1974; Cooper 1983). Hence their species name, meaning "humble" (Jordan and Evermann 1896).

Orangespotted Sunfish are utilized by other species in varying degrees as a forage species. Barney and Anson (1923) found that their numbers fell substantially in late summer due to predation by other fishes. Thus, one value of the species lies in its use as forage for other fishes of angling quality, especially in cultures of Largemouth Bass. The potential for their control of mosquitoes is also discussed by these authors. Lagler and Ricker (1942) found that Yellow Bass (*Morone mississippiensis*) ate Orangespotted Sunfish. Cross (1967) considers that where abundant, they may also provide significant forage for larger centrarchids. Krska and Applegate (1982) found *Lepomis humilis* to be an important food resource of young Muskellunge. However, Buck and Cross (1951) declared the species to be "generally considered detrimental", and that specimens were rarely found in game fish gut contents, perhaps due to their long dorsal spines.

Orangespotted Sunfish may also impact negatively on other more desirable species. Luce (1933) considered it a "weed" since it consumes food likely to be useful to larger fishes. Lagler and Ricker (1942) as well as Clark (1943, 1960) and Cross (1967) suggest them to be undesirable in some locations because of their competition for food with more valuable species. Bennett (1943) states emphatically that the species "never grows to a desirable size and should never be stocked in artificial lakes", given that large populations had crowded out other centrarchids in some situations. Because of their diminutive size and competition with Bluegill, Shields (1955) also considered them undesirable.

Clark (1960) states that *Lepomis humilis* also compete for nesting areas with Bluegill. Where sympatric, competition with the Green Sunfish may also occur (Trautman 1981). In contrast, Forbes and Richardson (1920) suggest that their competition with other centrarchids is minimal due to differences in their feeding structures.

Also of significance is that the species has been used as an experimental subject in various toxicity investigations (Shelford 1917; Gould 1962; Gould and Irwin 1965; Petersen 1979; Petersen et al. 1986), and has shown itself to be an excellent test and laboratory animal.

Evaluation

Orangespotted Sunfish populations located in Ontario appear to be indigenous, are extremely few, and are restricted in distribution. Captures have shown them to be generally in low abundance, although evidence points to some populations being self-perpetuating. The known distribution pattern and high frequency of hybrids in some catches suggests that Canadian populations represent the leading edge of a northward range extension by the species. Because their

Canadian distribution is very restricted and on the fringe of the species' range, and their numbers are low but do not appear to be in immediate peril, a designation of vulnerable would appear to be appropriate at this time.

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Status of the Bigmouth Buffalo, *Ictiobus cyprinellus*, in Canada*

CHERYL D. GOODCHILD

2168 Harcourt Crescent, Mississauga, Ontario L4Y 1W1

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The Bigmouth Buffalo, *Ictiobus cyprinellus*, is rare in Canada where its distribution is disjunct and exceedingly limited. In Saskatchewan, populations in some streams are large enough to support a limited commercial fishery but elsewhere in Manitoba and Ontario, populations are extremely small and tenuous judging from the very few specimens that have been collected. In contrast, the species is widespread and abundant throughout the Mississippi River Basin in the United States. Primary limiting factors appear to be temperature and spring flooding to elicit spawning. At the extreme northern limit of its range in Canada, Bigmouth Buffalo prefer a warm water habitat and may disperse further during a period of warmer climate. It is tolerant of eutrophication and turbidity.

Le buffalo à grande bouche, *Ictiobus cyprinellus*, est rare au Canada où son aire de répartition est sporadique et extrêmement limitée. Dans une petite région de Saskatchewan, les populations sont suffisamment importantes pour justifier une exploitation commerciale de petite envergure, mais ailleurs, au Manitoba et en Ontario, elles sont extrêmement réduites et sporadiques si l'on en juge d'après les très rares spécimens qui ont été capturés. Par contre, l'espèce est répandue et abondante dans tout le bassin du Mississippi aux États-Unis. Les principaux facteurs limitants semblent être la température et les crues printanières qui conditionnent la fraye. À l'extrême nord de son aire de répartition au Canada, le buffalo à grande bouche préfère un habitat caractérisé par une eau chaude, et pourrait se disperser davantage en période de climat plus clément. Il tolère l'utrophisation et la turbidité.

Key Words: Bigmouth Buffalo, *Ictiobus cyprinellus*, buffalo à grand bouche, Catostomidae, buffalofishes, rare and endangered fishes, status, Canada.

The Bigmouth Buffalo, *Ictiobus cyprinellus* (Valenciennes 1844), is characteristically a plains sucker (Figure 1) with an extremely limited and disjunct distribution in Canada. It typically inhabits slow, sluggish or still waters of larger rivers, oxbow and flood plain lakes, reservoirs, and lakes (Scott and Crossman 1979; Lee et al. 1980). A large deep-bodied, laterally compressed sucker, it closely resembles other buffalofish, (*Ictiobus* sp.), and is difficult to separate from *Ictiobus niger*, the Black Buffalo, the only other buffalofish found in Canada (Smith 1979). Comparative characters of three species of *Ictiobus* described by Crossman and Nepszy (1979) may assist identification. *Ictiobus cyprinellus* also resemble Carp (*Cyprinus carpio*) and members of the genus *Carpiodes* (Scott and Crossman 1973; Trautman 1981).

Bigmouth Buffalo are described as robust with a slightly compressed body. The back is not highly elevated. The large oblique mouth and thin lips are key characters for identification. Usually, there are 24 to 28 dorsal rays and nearly 100 gill rakers. The lower pharyngeal teeth are thin and weak, being more than twice as high as wide (Crossman and Nepszy 1979). Bigmouth Buffalo have a prominent, complete, almost straight lateral line with between 32 to 43 scales (Pfleiger 1975; Trautman 1981); however, Canadian specimens have lateral line scale counts of 39 to 41 (Scott and Crossman 1973). Fin ray counts are also highly variable with Canadian specimens having counts at the upper end of the range.

The colouration is generally described as follows: back, upper side and head, dull brown to olive, sides lighter to yellowish, ventral surface white with dusky to gray fins. The colour may be light bluish-grey (Harlan and Speaker 1956; Trautman 1981). Reported differences in colour during spawning are described as follows: upper side more coppery, pale green to bluish, bluish; dorsal and caudal fins drab gray; the pelvic fins lighten and the pectoral fins become dull white (Harlan and Speaker 1956; Scott and Crossman 1973). Breeding males are reported to be slightly darker (Pfleiger 1975).

Noticeable nuptial tubercles were reported for the first time by Morris and Burr (1987) from male *Ictiobus cyprinellus* in Illinois. Tubercles were distributed over much of the body including head, caudal peduncle and fin rays. Previously, nuptial tubercles had not been reported for either sex of this species (Scott and Crossman 1973; Pfleiger 1975).

Potentially extremely large, a specimen from Spirit Lake, Iowa, was reported to weigh 36.3 kg (80 lb) [Harlan and Speaker 1956]. Most adults,

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

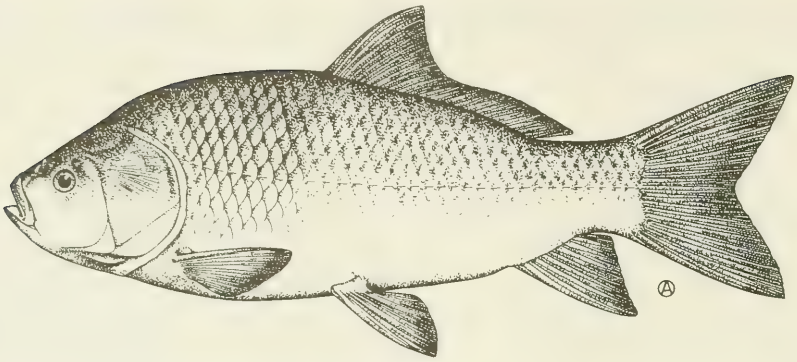

FIGURE 1. Bigmouth Buffalo, *Ictiobus cyprinellus* [drawing by A. Odum from Scott and Crossman (1973) by permission].

however, are under 4.5 kg (10 lb) and less than 410 mm (20 inches) in length (Smith 1979). In Canada, they are usually 254 to 457 mm (10 to 18 inches) in length (Scott and Crossman 1973).

Distribution

North America: The Bigmouth Buffalo is widespread throughout the Mississippi River Basin but the only drainage system of the Atlantic slope occupied is that of the Great Lakes system.

It is found from Lake Erie south through the Ohio and Mississippi River basins (in Ohio, West Virginia, Kentucky, and Tennessee) to the Tennessee River in northern Alabama, south through Mississippi and near the Gulf of Mexico in Louisiana, northwest through eastern Texas and Oklahoma (rare), north through Kansas, Nebraska, South Dakota and North Dakota and west to the Milk River drainage in central Montana. From Illinois in the Mississippi River drainage, it ranges northwest through western Minnesota and north in the Red River into Manitoba and west into Saskatchewan (Figure 2) (Johnson 1963; Scott and Crossman 1973; Lee et al. 1980). Recent collections place it in the Lake of the Woods, northwestern Ontario (*see* Canadian Distribution below). It is absent from the Lake Superior drainage (Eddy and Underhill 1974).

Introduced into Arizona, it is well established in some impoundments and it also occurs in the Gila River drainage. It has been introduced into California in the Los Angeles aqueduct system as well (Johnson 1963).

The Bigmouth Buffalo appears to be native to Lake Erie. A specimen was reported from Rockport, Ohio by Kirkland as early as 1854 (specimen in the Harvard Museum of Comparative Zoology). Hubbs (1930) thought it sporadically present in the Lake Erie watershed prior to 1900. Current population levels are likely a result of the United States Government stocking of Bigmouth Buffalo in western Lake Erie and Sandusky Bay in approximately 1920. By 1949, numbers had increased to the level whereby Bigmouth Buffalo contributed substantially to the commercial fishery in the United States portion of Lake Erie (Trautman 1981).

Canada: In Canada, the distribution of *Ictiobus cyprinellus* is disjunct and limited. It occurs in: western Lake Erie, Lake St. Clair the St. Clair River and some tributaries, Lake Ontario, possibly Lake of the Woods in Ontario, the Red and Assiniboine Rivers and recently Delta Marsh (Lake Manitoba) in Manitoba, and west in the Qu'Appelle River system in central Saskatchewan (Figure 3).

The first published record for this species in Canada may have been that of Gilchrist listed under the name *Ictiobus bubalus* (Scott and Crossman 1973).

Ictiobus cyprinellus may have dispersed into Lake Erie postglacially or, more recently, because of changes in physical barriers and short-term climatic changes. It probably occupied a Mississippi refugium and may have used the Grand Valley outlet and glacial Lake Warren as an avenue of dispersal. In recent historical times, however there are many documented crossovers. Dispersal of the Bigmouth Buffalo is possibly temperature dependent as it may be restricted to the 22.5°C July isotherm (N.E. Mandrak, personal communication).

Although the species has been known from the Ohio waters of Lake Erie since the mid-1800s, it was not taken in the Canadian waters of Lake Erie until 1957 when an individual weighing 8.2 kg (18 lb 2 oz) was caught by a commercial fisherman in Long Point Bay [Royal Ontario Museum (ROM) 1971] (Scott 1957). It has been collected on only two subsequent occasions; from Port Dover in 1968 [ROM 27749] and from Long Point Bay in 1972 [ROM 28266].

Why Bigmouth Buffalo should be well established in the United States' waters of Lake

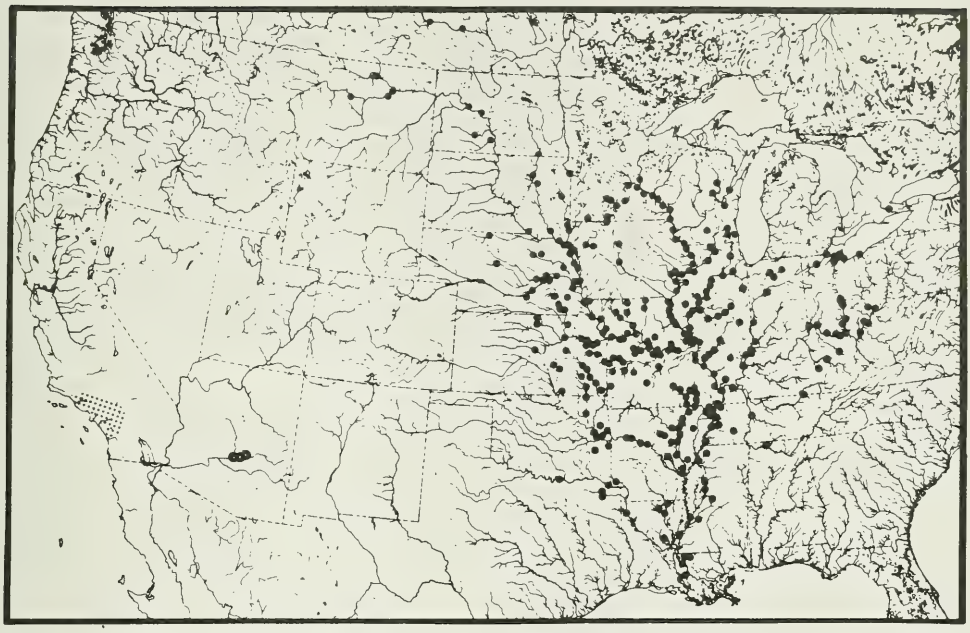

FIGURE 2. North American distribution of the Bigmouth Buffalo, *Ictiobus cyprinellus* (adapted from Lee et al. 1980).

Erie and apparently uncommon (sparse) in the Canadian part of the lake might be explained by the temperature requirements of this species. Its gradual movement into Canadian waters may be the result of an overall climatic warming trend. Increased turbidity in the lake may also provide access to a tolerant species such as the Bigmouth Buffalo. In a recent study, fish species having the potential to invade the Great Lakes during a period of climatic warming were identified based on a discriminant function analysis of ecological characteristics. The Bigmouth Buffalo was one of the species that proved to have significant invasion potential (Mandrak 1989).

Recently, the Bigmouth Buffalo has been collected from the St. Clair River by the Ontario Ministry of Natural Resources (OMNR) during electrofishing in "areas of concern" in the Great Lakes, as designated by the International Joint Commission. One specimen was electrofished from the northern part of the St. Clair River towards Lake Huron [A0CMNR86]. Two other specimens were collected at the outlet of the Lambton Generating Station [A0CMNR86]. Three additional specimens were collected from the Thames river at Jeanettes Creek [ROM 36582].

Its occurrence in the Bay of Quinte, Lake Ontario [ROM 37952] may be the result of an accidental introduction. The species is imported live from the United States and is often sold in Chinese fish markets. OMNR staff (Maple District) collected live specimens of several species not indigenous to Ontario, including *Ictiobus cyprinellus*, at Toronto markets (G. Goodchild, Fisheries Branch, Ontario Ministry of Natural Resources, Toronto, Ontario; personal communication). A specimen purchased at a Toronto market is in the ROM collection [ROM 0].

Collections of Bigmouth Buffalo from the Lake of the Woods, in northwest Ontario represent a significant extension of the range of this species in Ontario. A specimen was collected 27.4 km north of Rainy River in June 1973 [NMC: Canadian Museum of Nature 70-0125A]; and another specimen was collected from Whitefish Bay in October 1973 [ROM 30431].

Bigmouth Buffalo were absent from collections in the southern part of Manitoba for many years. They were reported from the Red River of the North by Eigenmann (1895). Hinks (1943) reported only one specimen of 12.7 kg (28 lb) from southern Manitoba and Scott and Crossman (1973) considered it rare to absent in the Red and Assiniboine Rivers. In 1982 and 1983, however, Bigmouth Buffalo were collected in Delta Marsh at the south end of Lake Manitoba (Stewart et al. 1985). This represent a significant extension of the range of this species in Manitoba and also verifies its continued existence in the Province. Recent collections from Lower Devil Lake in the Lake Winnipeg drainage [ROM 40369] and from the Red River near East Selkirk [ROM 35118] provide further evidence of a more extensive distribution.

FIGURE 3. Distribution of *Ictiobus cyprinellus* in Canada.

The Assiniboine River Floodway which diverts floodwater from the river into Lake Manitoba near Delta Marsh was probably the avenue of dispersal used by a number of species (including Bigmouth Buffalo) recently reported from Lake Manitoba. The floodway was opened briefly in 1970 but the west dike, which allows excess water to flow directly into Delta Marsh, was not opened until 1974 (Stewart et al. 1985). Further substantiation is the recent report of *Ictiobus cyprinellus* from the Assiniboine River in Manitoba (Crossman and McAllister 1986).

Bigmouth Buffalo may have originally dispersed into Manitoba from the Mississippi River via the Red River. Stewart et al. (1985) suggest that it entered the Red River after 2000 BP. Glacial Lake Agassiz was probably not involved in the dispersal as Bigmouth Buffalo likely invaded much later than the recession of the ice flows due to limiting water temperature (N.E. Mandrak, personal communication). Lake Agassiz is generally considered to have been formed earlier than other glacial waters (Radforth 1944) and Bigmouth Buffalo is a warm water species limited to the southern part of the Hudson Bay watershed. There are many species which occur in the Red River but not in the Souris River. Some have moved upstream into the English-Winnipeg system which possibly explains its occurrence in the Lake of the Woods. Others such as the Bigmouth Buffalo, have dispersed into the Assiniboine-Qu'Appelle system and become established (Crossman and McAllister 1986).

In Saskatchewan, Bigmouth Buffalo are abundant in the eight larger lakes of the Qu'Appelle drainage system (Johnson 1963; Atton 1983). Extensive seining of the Frenchman, Souris, and Assinboine river drainages in Saskatchewan has failed to disclose its presence there. Despite its occurrence in the Milk River of Montana, part of the Missouri drainage, it apparently does not occur in the Missouri drainage of Canada and is excluded from the distributional list of fishes in the Canadian section of the Missouri drainage (Willcock 1969).

Dispersal into Saskatchewan was probably through postglacial connections at the headwaters of the Mississippi and Red river systems. The headwaters of these systems are near Big Stone Lake and Lake Traverse on the South Dakota-Minnesota border and they were, apparently, connected during late glacial time. Today, the

divide may still be incomplete and headwaters may merge during spring floods (Johnson 1963).

Protection

Although it is considered to be of special concern in Manitoba (Johnson 1987), no specific protection for this species exists in Canada other than that afforded by habitat sections of the Fisheries Act.

Bigmouth Buffalo are not considered a game species, and therefore, are not protected as such. The species is rarely taken on a hook and line and is not a generally sought after species in Canada. Thus, it is not likely to be susceptible to angling pressure.

While commercially important in the United States portion of Lake Erie, it has not contributed to the Canadian catch and is not specifically protected by Canadian regulations (J. Tilt, Fisheries Branch, Ontario Ministry of Natural Resources, Toronto, Ontario; personal communication).

Population Sizes and Trends

There has been insufficient assessment to accurately judge whether Canadian populations of Bigmouth Buffalo are increasing or decreasing in abundance. In the Qu'Appelle system, Saskatchewan, they are abundant enough to support a small commercial fishery. Elsewhere in Canada, Bigmouth Buffalo exist in extremely low numbers. The species was thought to be absent from Manitoba for many years. Although recent collections from the Red River, Lower Devil Lake, and Delta Marsh (*see* Distribution above), indicate its continued existence in Manitoba, the numbers are too low to be encouraging. Populations in Manitoba may be extremely tenuous.

Bigmouth Buffalo appear to be on the increase in southwestern Ontario. Its distribution may be expanding slightly based on recent collections from the Thames River and the St. Clair River but very few individuals have been collected and no population trends can be determined.

In Saskatchewan, there is an erratic commercial fishery for Bigmouth Buffalo. The population in the Qu'Appelle drainage, Saskatchewan, is probably dependent on the sporadic production of strong year-classes (Johnson 1963). The 1948 year-class predominated in lakes studied during the mid 1950s. Johnson (1963) found that it contributed 88% of Bigmouth Buffalo caught in 1955 and approximately 82% of those caught in 1956. In fact, the 1948 year-class outnumbered all other year-classes in all the lakes sampled and no appreciable spawning or fry survival occurred in the years 1949 to 1954. Poor reproduction occurred in 1955 as well, but there was somewhat better success in 1956. Overabundance of the 1948 year-class may have resulted in a much slower growth rate due to intra-specific competition. Late maturity of Bigmouth Buffalo was probably directly related and self-limiting, affecting reproductive rate in subsequent years. Dramatic changes in year-class strength may reflect a lack of specific requirements which may, in turn, make the species particularly vulnerable.

Despite extensive trap netting in 1983, no juvenile Bigmouth Buffalo were caught in the Delta Marsh, Manitoba (Stewart et al. 1985). This further supports the theory that there is an extreme variation in year-class abundance for this species, at least in the northern extremity of its range.

Large fluctuations in year-class strength have been noted in other studies of Bigmouth Buffalo populations. In North Dakota, dramatic increases in previously strong year-classes were attributed to loss of optimal spawning areas (Willis 1978). In Lake Oahe, a Missouri River reservoir, Bigmouth Buffalo were dominated by three strong year-classes. The 1962 year-class was exceptional, 14 to 16 times more abundant than the 1965 year-class at ages IV and V respectively (Moen 1974). Recruitment appears to be sporadic among buffalofish populations in other waters as well.

In the United States, Bigmouth Buffalo populations tend to be relatively stable and there are few reports of drastic declines. Generally, the species appears to be maintaining or increasing in population numbers and distribution. Its decrease in abundnace and distribution in Minnesota and North Dakota is an exception (Eddy and Underhill 1974).

If size, as well as number of individuals, is considered, the species is sometimes incredibly abundant. Along the Mississippi River and its tributaries there is a significant inland fishery, and it is of considerable commercial importance in many states (Scott and Crossman 1973; Becker 1983). Although abundance in Minnesota has decreased, tremendous numbers continue to be taken by commercial fishermen in Lac La Croix during summer and from the Mississippi River near Winona in winter. In the early 1900s to mid-1950s, spawning runs in central and southern Minnesota contained similar vast numbers (Eddy and Underhill 1974).

Habitat

Bigmouth Buffalo may inhabit deeper pools of large streams, shallow overflow ponds, natural lowland lakes and man-made impoundments; usually in moderate to slow current (Pfleiger 1974; Trautman 1981). Pfleiger (1975) perceived that they occur in schools at midwater or near the bottom. In Saskatchewan, Bigmouth Buffalo

occupy shallow lakes with a maximum depth varying from 5 m to 30 m. Capture data indicate they prefer water shallower than 5 m and the maximum depth of capture was 8.5 m (Johnson 1963). They are common in Lake Poinsett, South Dakota, which has a maximum depth of 5.5 m (Starostka and Applegate 1970). In Wisconsin, they are encountered most frequently in water more than 1.5 m deep over substrates of mud, silt, sand, gravel, clay and rubble (Becker 1983).

The species is noteworthy for its tolerance to turbidity which is evidently higher than in other species of buffalofishes (Pfleiger 1975). Its sustained abundance in the Ohio River since 1925 suggests that species with large terminal mouths may be more suited to turbid water conditions and rapid silting of stream bottoms than species with smaller, inferior, mouths such as Smallmouth Buffalo (Trautman 1981). In Lake Erie, Bigmouth Buffalo are most abundant in the upper half of Sandusky Bay where the water is often extremely turbid.

The species exhibits a preference for warm, highly eutrophic, waters. Bigmouth Buffalo are abundant in Echo and Pasqua Lakes in Saskatchewan, which are described as highly eutrophic with heavy standing crops of benthic fauna and plankton. Dense blue-green algal blooms occur frequently and thermal conditions range from almost complete mixing throughout summer to the development of a pronounced thermocline (Johnson 1963). In Clear Lake, Iowa (a turbid prairie lake), Bigmouth Buffalo were most abundant in vegetated areas (Stang and Hubert 1984). Reservoirs in Arizona stocked with Bigmouth Buffalo in the 1920s, are described as basically clear, except near areas of silt or high nutrient input where planktonic algae may produce high seasonal turbidity. In Roosevelt Lake and Apache Lake, Arizona, freezing rarely occurs and surface temperatures may exceed 30° C with pronounced summer stratification. These lakes are also somewhat saline, indicating that Bigmouth Buffalo are tolerant of a mild degree of salinity (Minckley et al. 1970). Roosevelt Lake has fluctuating water levels and conditions of turbidity. Bigmouth Buffalo are abundant in Lake Poinsett, the largest natural lake in South Dakota. It is eutrophic and devoid of emergent aquatic vegetation (Starostka and Applegate 1970).

Bigmouth Buffalo are able to endure low oxygen tensions and high water temperatures. In a test, oxygen was reduced to 0.9 mg.L^{-1} and no deaths occurred (Gould and Irwin 1962). The maximum temperature recorded during capture of this species is 31.7° C (89° F) (Proffitt and Benda 1971).

Spawning occurs in shallow bays or small tributary streams (Eddy and Underhill 1974). Bigmouth Buffalo from Lake Erie have been observed spawning in tributary streams of Sundusky Bay, even ascending small ditches. Individuals exceeding 11.3 kg (25 lb) were captured in shallow ditches only a few feet wide (Trautman 1981). They readily invade marshes, tributary streams, ditches, and backwaters during spring flooding (Johnson 1963).

Bigmouth Buffalo share an environment with predacious fishes such as Northern Pike (*Esox lucius*), Black Bullhead (*Ictalurus melas*), Burbot (*Lota lota*), Yellow Perch (*Perca flavescens*), and Walleye (*Stizostedion* sp). In Pasqua Lake, Saskatchewan, the species most often found associated with Bigmouth Buffalo were Yellow Perch, White Suckers (*Catostomus catostomus*) and Spottail Shiners (*Notropis hudsonius*) [Johnson 1963].

Distribution of *Ictiobus cyprinellus* in Canada is restricted and localized. They are apparently tolerant of changes in habitat associated with turbidity and eutrophication but the amount of critical habitat has not been estimated. Habitat change, resulting from human interference, possibly increases the amount of suitable habitat for Bigmouth Buffalo. For instance, it fares well in man-made water bodies such as reservoirs. Protection of areas of suitable habitat does not appear to be necessary at this time.

General Biology

Reproductive Capability: Johnson (1963) provides considerable information on the life history of the Bigmouth Buffalo in Canada. It appears, however, that the individuals he studied, from lakes in Saskatchewan, matured later and had slower rates of growth than in most other areas. Bigmouth Buffalo may have considerable variability in age of maturation. Harlan and Speaker (1956) report sexual maturity is attained in the third year and found that pond-reared fish spawned at four years of age. Although age of spawning has been reported from as young as one year of age (Johnson 1963, *after* Swingle 1957), in Pasqua Lake, Saskatchewan, maturity was delayed. Gonads of 360 females less than 482 mm (19 inches) long, probably 7 to 9 years of age, were examined and only 19 were mature. The largest immature fish seen was a female of 475 mm (18.7 inches). This is probably the corollary of slow growth due to an extremely dense year-class (1948) and the cooler temperatures at this latitude. Males reach sexual maturity at a considerably smaller size than females. They begin to mature after attaining a length of 305 mm (12 inches) and most males are mature in the range of 356 to 379 mm (14.0 to 14.9 inches) [Johnson 1963].

Burr and Heidinger (1983) observed groups of three or more individuals spawning in 0.5 to 0.75 m

deep water in Crab Orchard Lake, Illinois. Usually, two tuberculate males aligned alongside one female in a "rush" along the water surface. Spawners then sank to the bottom and sometime assumed a vertical posture. Adhesive eggs were scattered over decaying vegetation and left unattended. Eggs are reportedly scattered and abandoned in shallow water over plant-debris, to which the eggs adhere until they hatch (Cross 1967; Eddy and Underhill 1974). In the Missouri River, however, fishes thought to be Bigmouth Buffalo were observed to be spawning by broadcasting eggs over rocks in water so shallow that the backs of the spawning fish were exposed (Pfleiger 1975).

Johnson (1963) found a storng relationship between spring flooding and reproductive success in spawning Bigmouth Buffalo. The strongest year-class was produced in 1948 when the greatest May run-off occurred. Earlier studies, involving pond culture of Bigmouth Buffalo found that the introduction of fresh water was necessary to activate spawning. If heavy run-off is the major factor governing reproductive success, then one would expect population peaks associated with flood years.

Bigmouth Buffalo spawn in spring during April, May, and as late as June in the northern part of the range in Saskatchewan. The sex ratio during spawning of large fish was two females to three males but, later in the season, was one female to five males (Johnson 1963). Optimal water temperatures for spawning are between 15.6° to 18.3°C (60° to 65°F), but eggs are laid in water up to 26.7°C (80°F) [Johnson 1963]. In Illinois, spawning occurred at the end of April in water 8° to 10°C (Burr and Heidinger 1983). Eggs hatch in about ten days at 16.7°C (62°F) [Eddy and Underhill 1974]. Johnson (1963) estimated the number of eggs contained in a 665 mm (26.2 inch) long individual at approximately 750 000. Over 400 000 eggs were estimated to be contained by a 4.5 kg (9.9 lb) female (Harland and Speaker 1956). Size of mature eggs range from 1.2 to 1.8 mm in diameter (Scott and Crossman 1973).

Length of young-of-the year from Ohio range from 43 to 102 mm (1.7 to 4.0 inches) in September and individuals reach 127 to 178 mm (6.0 to 7.0 inches) by about one year (Trautman 1981). Bigmouth Buffalo from Minnesota and Tennessee were compared up to age 7 and those from Minnesota were consistently longer at each age group (Carlander 1950).

Ictiobus cyprinellus from the Qu'Appelle River grew more rapidly than those from lakes in Saskatchewan, attaining an average length of 71 mm (2.8 inches) in the first summer. In Pasqua Lake, Saskatchwan, the largest young-of-the-year captured was 63 mm (2.5 inches) long in August 1956. The unique population Johnson studied in Pasqua Lake was severely affected by the extremely numerous 1948 year-class which, combined with the northern climate, resulted in a stunted population. Growth was exceedingly slow compared with that in Reelfoot Lake, Tennessee, where 3-year-old fish are nearly as long as a 9-year-old Pasqua Lake fish. Dominance of three strong year-classes (1959, 1960, 1962) apparently resulted in a reduced growth rate of Lake Oahe Bigmouth Buffalo, as well. Individuals of the 1962 year-class averaged 10 to 11% shorter and 36% lighter than those of the 1959 year-class (Moen 1974).

Adults are usually 590 to 1180 mm (15.0 to 30 inches) long and weigh from 0.9 to 13.6 kg (2 to 30 lb), although lengths of 1370 to 1570 mm (35 to 40 inches) and weights of 18.1 to 27.2 kg (40 to 60 lb) have been reported in Ohio. Maximum reported weight is 36.3 kg (80 lb) [Trautman 1981].

Johnson (1963) was confident in assigning age groups for fish up to 10 years of age. Age determinations for older fish were progressively less reliable with increasing age. Moen (1974) found that age determinations became increasingly difficult beyond age V, especially for males. Bigmouth Buffalo from lakes in Saskatchewan included individuals estimated to be up to 20 years of age [696 mm (27.4 inches)]. Bigmouth Buffalo may have very long life spans judging from the extremely large size reportedly attained by some individuals.

Species Movement: The Bigmouth Buffalo is not generally considered to be a migratory species. It does, nonetheless, migrate in order to spawn in flooded marshes and tributary streams and may travel long distances in order to find suitable sites (Eddy and Underhill 1974; Cooper 1983). Although Johnson (1963) did not investigate movement, he did allude to spawning migration by indicating the species had been captured during spring in locations presumably associated with breeding movements.

Backer (1983) suggests that, in addition to migration in upstream spawning runs in spring, Bigmouth Buffalo may also participate in runs in September and October when high flood waters are present. In South Dakota, movement of marked fish was extensive. The maximum distance traveled was 379 km and the maximum rate of travel was 6.5 km per day (Moen 1974).

Behaviour/Adaptability: Starostka and Applegate (1970) determined that Bigmouth Buffalo greater than 236 mm exhibit little, if any, food selectivity and described it as an indiscriminant planktivore. In most instances, they found that subadults and adults consumed plankton in the same proportion as found in the limnetic

environment, ingesting primarily *Daphnia* and other cladocerans, copepods, and blue-green algae. Analysis of stomach contents indicated a succession in food habits as fry had consumed primarily benthic organisms.

The enlarged head and mouth, and structure of the gill rakers are indicative of planktonic feeding (Minckley et al. 1970). Stomach contents, from early studies, supported the conclusion that the Bigmouth Buffalo were predominantly plankton feeders. However, studies in Arizona indicate a near bottom feeding habit (Johnson and Minckley 1972); analysis of the diet of young, juvenile, and adult Bigmouth Buffalo in Pasqua and Echo Lakes, Saskatchewan, also revealed that many animals classed as bottom fauna are often taken as food (Johnson 1963). The organisms include chironomid larvae, miscellaneous insects, molluscs, amphipods and ostracods. The largest volume of food, however, was comprised of cladocerans and copepods, normally thought of as planktonic, yet both groups have members classed as creepers which spend a great deal of their life on a substrate and Johnson (1963) demonstrated these contributed to the diet of Bigmouth Buffalo. He found a tendency to increased utilization of benthic invertebrates by larger fish, contrary to the results obtained by Starostka and Applegate (1970). Diet is probably influenced by availability of foods rather than by active selection. Bigmouth Buffalo occupy a food niche overlapping both benthic and planktonic feeding (Johnson 1963). Minckley et al. (1970) suggest that Bigmouth Buffalo may utilize the organisms churned up by their "bouncing" feeding movements. They have been observed in hatcheries swimming at an angle of 55° to the bottom "skipping" back and forth as they sucked up food pellets. Similar feeding behaviour was described for non-captive individuals (Johnson 1963).

Changes in the ecology of a water body, brought about by human disturbance, often result in a drastic alteration of the biota. As Bigmouth Buffalo appear to be opportunistic feeders, they would be expected to be able to utilize an altered fauna. In some Arizona lakes that contain non-native species of plankton and benthic organisms, Bigmouth Buffalo are well established. They are also relatively tolerant of increased turbidity and eutrophication which often accompanies anthropogenic changes (Minckley et al. 1970).

Parasitic infections, particularly those which interfere with the feeding mechanisms of Bigmouth Buffalo may have detrimental effects on populations. Johnson (1963) found young fish heavily infected with spores of *Myxosporida* enclosed in prominent white cysts on the gills. The smallest fish were emaciated. Ectoparasitic copepods (*Argulus apendiculosus*) were also found on individuals in Saskatchewan. These are the only parasites recorded for this species in Canada (Margolis and Arthur 1979). Hoffman (1967) listed the following parasites of Bigmouth Buffalo: Trematoda, Cestoda, Nematoda, Acanthocephala, leeches, Crustacea. Bigmouth Buffalo kept in holding tanks appeared to be particularly susceptible to parasitic infections (Becker 1983).

There is a pronounced tendency to school during the summer. On warm still days, Bigmouth Buffalo spread out over the entire surface of lakes where they rest quietly in the upper 0.6 m (2 ft) of water. Often the dorsal fin projects above the surface. The behaviour is never observed on windy days. Commercial fishermen take advantage of this congregating behaviour by setting barrier nets (Johnson 1963).

The systematics of *Ictiobus cyprinellus* have not been studied in detail. There is no significant sexual dimorphism (Phillips and Underhill 1971). Species of *Ictiobus* appear to be a closely related group. In a biochemical study of the phylogenetic relationships of catostomid fishes, results indicated that there is close affinity between *Ictiobus bubalus* and *Ictiobus cyprinellus* and they hybridize naturally (Johnson and Minckley 1972; Bussjaeger and Briggs 1978). *Ictiobus cyprinellus* and *Ictiobus niger* have been artificially hybridized and progeny cultured (Lee et al. 1980, *after* Stevenson 1964).

Limiting Factors

Many factors found to be limiting to populations of other fishes apparently have little effect on Bigmouth Buffalo. Although they may share an environment with many large predacious fishes, there is little evidence of predation on young Bigmouth Buffalo, and certainly, large adults are probably free from any predation (Johnson 1963; Scott and Crossman 1973). The gibbous shape, combined with large size, probably makes them difficult to swallow.

Turbidity, siltation and eutrophication cannot be tolerated by many species of fish, but the Bigmouth Buffalo is evidently able to thrive under these conditions. It prefers warm, slow flowing, shallow waters with abundant bottom fauna and plankton. Ecological changes resulting from human activities tend to produce aquatic habitats of this nature and thus may even increase the amount of suitable habitat for Bigmouth Buffalo. Certainly, they thrive in impoundments and, in some cases, have become important in the commercial harvest of these reservoirs.

Prime among the limitations on this species is the requirement for spring flooding to elicit spawning. The very successful 1948 year-class

which comprised most of the individuals studied by Johnson (1963) was produced in a year when there was significant spring run-off. Little successful reproduction was observed in the years when freshets did not occur. Therefore, channelization and flood control measures may have detrimental effects on reproductive success.

Nevertheless, an extremely successful reproductive rate may be self-limiting. Overabundance of the species resulting in a high level of intraspecific competition may cause stunting and late maturity of individuals. Subsequent year-class strength may be extremely low or non-existent. In his studies of lake populations in Saskatchewan, Johnson (1963) surmised that the uniquely successful 1948 year-class was partly responsible for a distorted growth rate and misleading appraisal of size and age of sexual maturation. Strong and weak year-classes are very apparent (Scott and Crossman 1973) and females in Saskatchewan may not spawn every year.

The degree of interspecific competition has not been studied. There are indications though that the Bigmouth Buffalo may have a selective advantage in occuying a food niche that overlaps both benthic and limnetic feeding.

Heavy parasitic infestations, particularly by *Myxosporida* which are enclosed in cysts on the gills, may severely debilitate populations, due to interference with feeding mechanisms. The gill rakers of Bigmouth Buffalo are specialized for plankton feeding (Johnson 1963; Starostka and Applegate 1970).

Since Bigmouth Buffalo are generally considered to be a "rough fish", they are not protected by regulations that protect other more favoured species. Populations have been indiscriminately eliminated during attempts to remove unwanted species such as carp. Toxicants were used in Wisconsin which eradicated all fish species from the area treated. As a result, Bigmouth Buffalo are no longer present in many areas of the Upper Rock River drainage. Becker (1983) suggests that the classification of Bigmouth Buffalo in Wisconsin should be changed to sport fish status.

Special Significance of the Species

The blood of *Ictiobus cyprinellus* and *Ictiobus bubalus*, in common with only a few other species, contains unique cells called secretory granulocytes (Chlebeck and Phillips 1969). The function of these cells is unknown.

Bigmouth Buffalo are not usually considered sport fish and the species seldom takes a hook. In the lower Mississippi Valley, it is frequently taken on set lines baited with balls of dough (Jordan and Evermann 1923). In Wisconsin, fishermen seek the Bigmouth Buffalo with square dipnets from river banks and bridges or they pursue it on flooded marshes from rowboats and skiffs using spears (Becker 1983). Bigmouth Buffalo is becoming increasingly popular as a table fish and is an ethnic favourite. The meat is nutritious and considered to be superior to carp in taste. It is excellent when smoked (Becker 1983).

Under managed conditions, buffalo fishes have a great potential for producing high-level protein and culture could be profitable. A single trial of Bigmouth Buffalo in a 1/25 ha pond resulted in a yield of 287 $kg.ha^{-1}$ without fertilization of the pond or feeding of the fish (Cross 1967). Bigmouth Buffalo have been cultured in ponds since the early 1900s. The culture of trout and buffalofish (*Ictiobus* sp.) expanded in the 1950s but culture of *Ictiobus* dwindled by the early 1960s. In Arkansas, in 1979, 4000 metric tonnes of buffalofish were marketed, however, only about 600 metric tonnes were pond-raised (Shelton and Smitherman 1984). It is currently a prized cultured species in eastern Europe and the USSR. Becker (1983) suggests that the use of ponds receiving treated effluent water from sewage plants and cooling ponds at power generation sites, should be considered for the culture of Bigmouth Buffalo.

There is a significant commercial fishery for this species in the United States. Commercial fishermen from Iowa, Missouri, and Nebraska reported taking 120 327 kg of Smallmouth and Bigmouth Buffalo in 1976 and 1977. The species contributes a major portion of the commercial catch of the Mississippi River with yields of 672 $kg.ha^{-1}$ (600 lb/acre surface area) not uncommon in some areas (Harlan and Speaker 1956). In just the Wisconsin portion of the Mississippi River, from 1960-1964, the total harvest of buffalos (combined species) was 1 257 000 kg. Production in the Wisconsin waters of the Mississippi River has continued to be substantial. In 1976, for instance, 243 962 kg were captured with a cash value of $115 634. Bigmouth Buffalo contribute the greatest portion of the catch.

Ictiobus cyprinellus is considered to be of special concern in Manitoba but not in any states of the United States (Johnson 1987). Until recently *Ictiobus cyprinellus* was the only member of the genus *Ictiobus* to occur in Canada. In 1978, the Black Buffalo, *Ictiobus niger*, was first described, from the western end of Lake Erie in Canada (Crossman and Nepszy 1979). It has since been collected from several other locations in southwestern Ontario. It has also been considered by COSEWIC and has also been assigned a vulnerable status in Canada (Houston 1990). The Black Buffalo is considered to be of special concern in Kentucky, Mississippi, South Dakota, and West Virginia in the United States and is protected in Wisconsin (John-

son 1987). So few specimens of *Ictiobus* other than *Ictiobus cyprinellus* are seen from the Great Lakes that the characteristic features of other large *Ictiobus* are poorly known and, since they have a pronounced tendency to hybridize, the species may be readily confused.

Evaluation

The Bigmouth Buffalo is apparently flourishing in the Mississippi Valley watershed. It is also particularly tolerant of environmental degradation. In the United States part of its range, it is abundant and not in jeopardy.

The position of most Canadian populations, however, is extremely tenuous. Although Bigmouth Buffalo are indigenous, they are, apparently, at the extreme northern limit of their range in Canada. Except for a well established population in Saskatchewan, the species exists in extremely low numbers elsewhere. Temperature may be the crucial limiting factor that restricts its distribution in Canada as there seems to have been ample opportunity for Bigmouth Buffalo to disperse into Canadian waters, especially Lake Erie. There is some indication that Bigmouth Buffalo may disperse further into Canadian waters during a period of warmer climate. Its competitiveness may be enhanced by certain types environmental degradation.

Since the species has potential economic value, is at the fringe of its range, and generally occurs in low numbers, it should be classified as vulnerable (rare) in Canada.

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Status of the Black Buffalo, *Ictiobus niger*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of the Black Buffalo, *Ictiobus niger*, in Canada. Canadian Field-Naturalist 104(1): 98-102.

The Black Buffalo, *Ictiobus niger,* has only recently been reported from Canadian waters in the western end of Lake Erie. One earlier United States record for western Lake Erie is also known. The species is less common than the other buffalofishes and appears to have declined or been extirpated in portions of its United States range, but has extended its range elsewhere through introductions. The lower Great Lakes, however, appear to be within the native range. The species is rare in Canadian waters.

Ce n'est que récemment que le buffalo noir, *Ictiobus niger*, a été signalé dans les eaux canadiennes à l'extrémité ouest du lac Erié. On connait également une mention américaine antérieure pour l'ouest du lac Erié. L'espèce est moins répandue que les autres buffalos et semble avoir diminué ou avoir été déracinée dans certaines zones de son aire de dispersion aux Etats-Unis, mais elle a étendu son aire ailleurs grâce à des introductions. Cependant, les lacs inférieurs des Grands Lacs semblent être dans les limites de l'aire de dispersion naturelle. L'espèce est rare dans les eaux canadiennes.

Key Words: Black Buffalo, *Ictiobus niger*, buffalo noir, Catostomidae, suckers, buffalofish, rare and endangered fishes.

The buffalofishes (genus *Ictiobus*) are large suckers (family Catostomidae) characteristic of the rivers, lakes and larger streams of the Mississippi drainage basin. They are easily separated from other genera of the family (Catostomidae are represented in North America by 10 genera and some 65 species, seven of the genera have Canadian distributions) by their large size and the shape of the head and body which more closely resemble those of Carp (*Cyprinius carpio*). They are easily distinguished from the latter by lack of barbels, typical suckerlike mouth, and difference in colour. Amongst the suckers, buffalofishes most closely resemble the carpsuckers (Genus *Carpiodes*) from which large specimens can be distinguished by the thicker body and upward curve of the snout (*see* Clay 1962; Cross 1967), but juveniles may be confused with those of *Carpiodes* sp.

The Black Buffalo, *Ictiobus niger* (Rafinesque 1820), is the smallest of the buffalos, commonly 90 to 60 cm in length and 0.5 to 4.5 kg in weight (Figure 1). The species can be distinguished from the other buffalos by the darker colour, thicker body and ventral mouth (Clay 1962). The dorsal surface is usually slate-grey to black, the sides brownish and the belly yellow to white.

Distribution

In Canada, the species was first described from a single specimen from the western end of Lake Erie [Crossman and Nepszy 1979; ROM (Royal Ontario Museum) 34562]. The Black Buffalo has also been reported from Boston Creek [Haldiman — Norfolk County; 49°59′42″N, 80°16′18″W: OMNR (Ontario Ministry of Natural Resources) 575 #42] of the Lake Erie drainage and in central Lake Erie [ROM 53971]. The OMNR has recorded collections from Carp Creek, a tributary of the Saugeen River in Grey County [44°08′36″N, 80°32′00″W; 44° 09′36″N, 30° 54′24″W: OMNR #'s 83, 43, and 44 respectively]. There is one record of the species from the Niagara River near St. Catharines [43°19′27″N, 79°03′01″W: AOCMNR 86: OMNR]. (Figure 3).

These records have been checked by staff of the Royal Ontario Museum and the Boston Creek and Carp Creek records are catalogued as *Castostomus* sp. unidentified. The Niagara river specimen was returned to the water alive and cannot be verified (E. J. Crossman, ROM, Toronto, Ontario; personal communication).

In the United States, the Black Buffalo is known from most large rivers and many smaller rivers of the Mississippi, Missouri and Ohio river basins (Figure 2). It has also been reported as rare and extirpated or depleted in the Calcasieu, Sabine, Bryos and Rio Grande drainages by the U.S. states concerned, but these may be introduced populations or misidentifications of the more locally common Smallmouth Buffalo, *Ictiobus bubalus* (Hubbs and Lagler 1958; Shute 1980).

In the Great Lakes, the species has only been reported from southern Lake Michigan and Lake Erie (Hubbs and Lagler 1958). Although

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

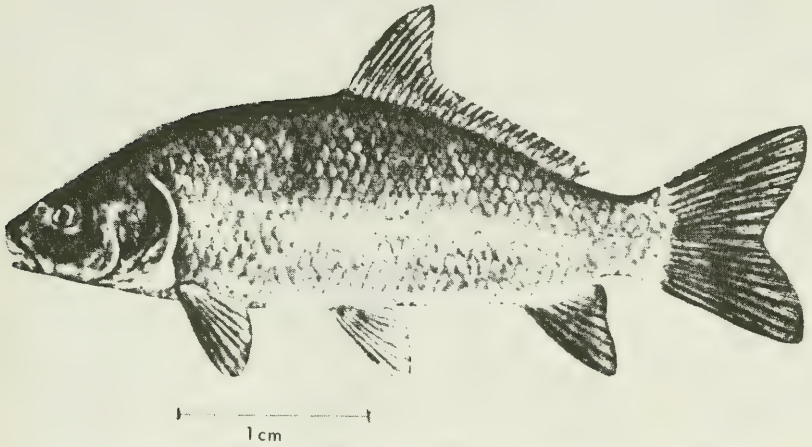

FIGURE 1. Black Buffalo, *Ictiobus niger* (drawn from photograph in Cross 1967).

Trautman (1957) indicates that the lower Great Lake populations resulted from introductions, Hubbs and Lagler (1998) disagree and consider the species to be native in these waters. Trautman (1957) does note the lack of early information on the species due to confusion with the Smallmouth Buffalo and its less common occurrence. He also indicates that hybrids between the species had been taken in Sandusky Bay, thereby supporting the existence of the species in Lake Erie. Moore (1968) listed the species for Lake Erie. The recent Canadian collections (1975 to 1987) confirm the presence of the species in Lake Erie.

Protection

There is no specific protection for this species in Canada although general protection is available through the Fisheries Act. In the United States, the Black Buffalo is listed as a species of special concern in Kentucky, Mississippi, South Dakota and West Virginia. It has been listed as protected in Wisconsin (Johnson 1987).

Population Sizes and Trends

Although Trautman (1957) indicated that the species was probably introduced to the lower Great Lakes, Hubbs and Lagler (1958) state they are native (*see* Distribution). Since the species is abundant in Ohio and can easily be confused with the Smallmouth Buffalo, especially smaller individuals (Smith 1979), it has probably gone unnoticed. Moreover, in the past, many fishermen and fisheries biologists believed this species to be a hybrid between the other two species and it was referred to as the Mongrel Buffalo Fish. The species is of no commercial interest and no attempt to ascertain populations in the Great Lakes have been made. Thus, it is probably native to Lake Erie and may have gone virtually undiscovered there because of its rarity, unimportance and similarity to the other species.

The origins of this species in Canada and its occurrence in the Lake Huron drainage may be questionable, but based on its apparent rarity and other factors as discussed above, it is not unreasonable to assume that this fish may be native to the Lake Huron drainage as well and have previously gone unnoticed. On the other hand, it may have been introduced through release of bait fish. More information on the distribution of the species in Canada is required before this question can be resolved. However, the species appears to be native to Canadian waters, at least in Lake Erie, where it is relatively rare.

In the United States, the species is still listed as common in some parts of the range, but has been depleted or extirpated in other parts (Smith 1979; Shute 1980). The distribution is sporadic, related to availability of suitable habitat and the species seems intolerant of pollution. On the other hand, they do adapt to impoundment conditions (Cross 1967). Nowhere are they as abundant as the other two buffalos.

Habitat

No specific information is available on the habitat preferences of the species, but Black Buffalo are often found in association with the Smallmouth and Bigmouth (*Ictiobus cyprinellus*) buffalos. However, Trautman (1957) indicated the preferred habitat was intermediate to that of the other two. The Bigmouth Buffalo is often found in shallow turbid pools, overflow ponds and lowland lakes and has a high tolerance for turbid waters (Trautman 1957). The Smallmouth Buffalo, on the other hand, frequents less turbid waters and its

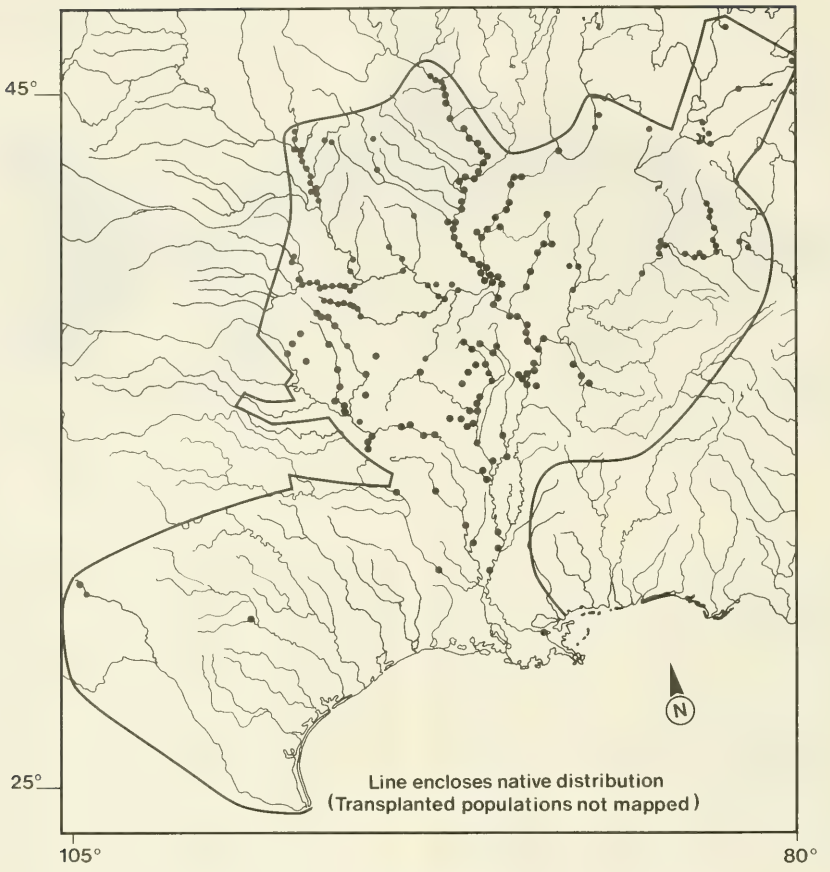

FIGURE 2. Canadian records of the Black Buffalo (see text for details).

most commonly found in the deeper, swifter, cleaner waters of larger rivers and does not move into flooded areas, remaining in the permanent river channels.

Although Trautman (1957) indicated that the species probably occupied a habitat intermediate to the Bigmouth and Smallmouth Buffalos, the habitat requirements seem to be closer to those of the latter. Clay (1962) stated that the species is intolerant of pollution; it is usually found in the deeper water of larger rivers, but may be found in marginal lakes (Smith 1979).

General Biology

There is little information on the biology of the species, but feeding and reproductive habits are said to be similar to those of the other buffalos (Smith 1979). Growth rates for the species in a Kansas reservoir were reported by Green and Cross (1956), and Carlander (1969) provides some additional age and growth data. Like most suckers, buffalos spawn in the spring after runoff raises stream levels. Thousands of eggs [up to 400 000 in larger fish, *see* Harlan and Speaker (1951)] are scattered over the bottom in shallow waters and abandoned. Hatching is assumed to occur in about 10 days at 15°C [if similar to the Smallmouth Buffalo — *see* Smith (1979)] and young-of-the-year of all three species show up by mid-June (*see* Cross 1967; Smith 1979). Growth is rapid, young-of-the-year attaining 2 to 3 cm at the end of the first summer. They are sexually mature by age 3 at 22.5 to 39 cm in length and 0.5 to 2 kg in weight (Harlan and Speaker 1951; Carlander 1969). By seven years, lengths of 100 cm or more may be achieved and fish of up to 24 years of age are known (Carlander 1969). One Black Buffalo taken in Kansas was 104.1 cm long and weighed 12.7 kg (Cross 1967).

The species is benthic, feeding on plankton, insect larvae and vegetation; snails and small molluscs may also be important food items (Harlan and Speaker 1951). The species apparently hybridizes with Bigmouth and Smallmouth Buffalos where they are sympatric (Shute 1980).

FIGURE 3. Native distribution of the Black Buffalo, *Ictiobus niger* (adapted from Shute 1980).

Limiting Factors

No specific limiting factors have been indicated, except that the Black Buffalo has been reported as being intolerant of pollution (Clay 1962). The species is of little or no commercial interest and is relatively rare compared to other buffalos (Smith 1979). It is often taken by anglers using worms or doughballs for bait (Cross 1967) but is not a sought after species (Harlan and Speaker 1951).

Like the Smallmouth Buffalo, it seems less tolerant of turbidity (Trautman 1957) and may be limited by availability of suitable habitat and by damming of rivers for hydroelectric developments etc. It apparently does adapt to life in impoundments (Cross 1967). They may also be limited by competition with Carp (Cross 1967). The Canadian distribution may be limited by available habitat as the United States distribution has been shown to be sporadic, presence of the species being related to suitable habitat and water quality (Cross 1967).

Special Significance of the Species

Although of no commercial or sport interest, the species, like other buffalos, grows fast, does well in impoundments, and could be utilized as a source of protein. Its presence in the lower Great Lakes could be indicative of changing water quality. The extent of the Canadian distribution requires clarification.

Evaluation

The lower Great Lakes would appear to be the northern fringe of the native range of the species. Although locally abundant in some locations within the United States range, it is relatively rare as opposed to the other buffalos and has apparently declined or been extirpated in some parts of its range. United States and Canadian records for the species in Lake Erie are few and the species should be considered rare and vulnerable in Canada. Although only recently discovered in Canadian waters, there is no reason to suppose its presence in

western Lake Erie is recent. Earlier United States records for the lake are known and the species is not easily identified and can be confused with the Smallmouth Buffalo, and younger fish of all these species are difficult to distinguish.

Acknowledgments

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Status of the Golden Redhorse, *Moxostoma erythrurum*, in Canada*

CHERYL D. GOODCHILD

2168 Harcourt Crescent, Mississauga, Ontario L4Y 1W1

Goodchild, Cheryl D. 1990. Status of the Golden Redhorse, *Moxostoma erythrurum*, in Canada. Canadian Field-Naturalist 104(1): 103–111.

The Golden Redhorse, *Moxostoma erythrurum*, is known from the Lake Huron, Lake St. Clair, and Lake Erie drainages in southwestern Ontario. Recent records from the Niagara River in Ontario and the Red River in Manitoba, indicate that its range is either expanding or more extensive than had previously been thought. This species is difficult to identify and is often overlooked or misidentified. Three other species of *Moxostoma* are either threatened or rare in Canada. Canadian populations are contiguous with those in the United States, but are at the northern limit of the range of the species. Little is known of its biology in Canada, but it does not appear to be in great jeopardy at this time.

Le suceur doré, *Moxostoma erythrurum*, fréquente les bassins des lacs Huron, Sainte-Claire et Érié dans le sud-ouest de l'Ontario. Des données récentes, recueillies dans la rivière Niagara en Ontario ainsi que dans la rivière Rouge au Manitoba, indiquent que son aire de répartition est soit en expansion, soit plus étendue qu'on ne le croyait auparavant. L'espèce est difficile à identifier et passe souvent inaperçue ou est confondue avec une autre. Trois autres espèces de *Moxostoma* sont soient menacées, soient rares au Canada. Les populations canadiennes, qui sont voisines des populations américaines, sont cependant à la limite septentrionale de l'aire de répartition du suceur doré. On connaît peu de choses sur la biologie de l'espèce au Canada, mais elle ne semble pas particulièrement menacée à l'heure actuelle.

Key Words: Golden Redhorse, *Moxostoma erythrurum,* suceur doré, Catostomidae, suckers, *Moxostoma,* redhorses, status, Canada.

The Golden Redhorse, *Moxostoma erythrurum* (Rafinesque 1818), is generally gray to bronze or olive coloured shading to white on the belly, with a golden cast in large specimens or a silvery cast in younger fish (Figure 1). Anal and paired fins are yellow to reddish orange. Trautman (1981) suggests that fishes taken from polluted waters may have all fins orange or reddish-orange. Adults are generally 280 to 450 mm (11 to 18 in) long, weighing up to 0.9 kg (2 lb). A 660 mm (26 in) long specimen was reported from Lake Erie (Trautman 1981).

This species is difficult to distinguish from other members of the genus, particularly the Black Redhorse, *Moxostoma duquesnei*, and the Silver Redhorse, *Moxostoma anisurum*. Kott (1979) found the most useful character to differentiate Golden Redhorse from Black Redhorse in southwestern Ontario, is the lateral line scale count (LLS), which ranges from 39 to 44 in Golden Redhorse and from 45 to 48 in Black Redhorse. Brown (1984) found the character (LLS) was highly variable and age dependent in Indiana and suggested that it was taxonomically limited. The obtuse angle formed by the lower lips is suggested as the best character for discriminating Golden Redhorse (Scott and Crossman 1973; Brown 1984). Franzin et al. (1986) used body colouration, dorsal fin shape, and lower lip morphology in combination to separate three species of *Moxostoma*.

Although formerly thought to be present only in southwestern Ontario, it has recently been reported from the Red River, Manitoba (Franzin et al. 1986) and the Lake of the Woods, in northwestern Ontario (V. Macins, Ontario Ministry of Natural Resources, Kenora, Ontario; personal communication).

Distribution

North America: The Golden Redhorse is restricted to the freshwaters of eastern North America (Figure 2). It occurs south from Lake Ontario tributaries of western New York State, west of the mountains, through western Pennsylvania and West Virginia to Tennessee and the north of Georgia, Alabama and Mississippi, west through much of northwestern Arkansas, eastern Oklahoma and extreme northern Texas, north through southeastern Kansas, through the eastern parts of the states from Nebraska to North Dakota, east across central Minnesota, Wisconsin, Michigan, and into Ontario (Scott and Crossman 1973).

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

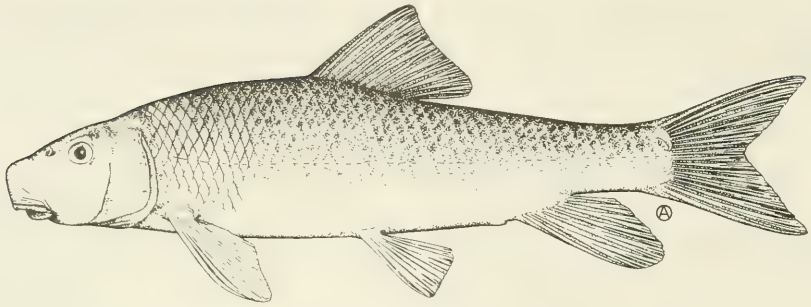

FIGURE 1. Drawing of Golden Redhorse, *Moxostoma erythrurum* [drawing by Anker Odum, from Scott and Crossman (1973) by permission].

Lee et al. (1980) include the Upper Red River of the North, the Lake of the Woods drainage, and the Roanoke and James drainages on the Atlantic slope. Recently, it has also been found (perhaps introduced) in the Potomac drainage. The Potomac records apparently reflect a new range extension since it is absent from most Atlantic coast streams (Cooper 1983). The range of the Golden Redhorse may be expanding westward as well. In Kansas, Clarke and Clarke (1984) have reported it from the Arkansas River 160 km (100 miles) west of previously known localities.

Canada: Until recently, in Canada, the Golden Redhorse was believed to be restricted to the drainages of Lake Erie, Lake St. Clair and southern Lake Huron, in southwestern Ontario. Golden Redhorse have been collected from 125 different locations in southwestern Ontario (Figure 3). The majority of the collections, however, have been made from a few major rivers and streams as follows: Catfish Creek, Grand River, Thames River, Nith River, Saugeen River, Sydenham River, Maitland River, and Nanticoke Creek.

Scott and Crossman (1973) state that it was present in the Lake Erie system as far east as the Grand River, but not apparently in the Niagara River. More recent evidence suggests it may also be present in the Niagara River drainage in south-central Ontario. A single specimen was collected at the mouth of Miller Creek, near its confluence with the upper Niagara River in 1980 [Royal Ontario Museum, Toronto: ROM 37372]. This is perhaps not surprising as in New York State it is known from many streams draining into the Niagara River as well as in tributaries to Lake Ontario (Smith 1985).

Dispersal into southwestern Ontario probably occurred before the arrival of man and was probably limited by temperature and suitable habitat (N. Mandrak, Department of Zoology, University of Toronto, Toronto, Ontario; personal communication). Postglacial dispersal into southwestern Ontario probably occurred through the Fort Wayne outlet of glacial Lake Maumee from a Mississippian refugium. Golden Redhorse occur in streams flowing into Lake Erie, Lake St. Clair and Lake Huron in Ontario. Niagara Falls, at Lewiston, was probably a barrier in both directions by approximately 12 400 B.P. (Calkin and Feenstra 1985) and restricted it from moving eastward into the Lake Ontario drainage. The expansion of the populations in New York State, however, probably occurred due to migration through the Gennessee River on a fairly recent basis, since construction of the canals in the Lake Erie watershed provides reasonably free access (N. Mandrak, personal communication).

Most recently, *Moxostoma erythrurum* has been reported from the Red River, Manitoba. Franzin et al. (1986) collected four adults about 1.5 km downstream from St. Andrew's lock and dam near Lockport, Manitoba on 9 October 1981. An unconfirmed report of four individuals from the Lake of the Woods area of Ontario (Dechtiar 1972) appears less doubtful with the recent collections in Manitoba and reports that Golden Redhorse occur in both the upper Red River (Lee et al. 1980) and Sheyenne River tributary in North Dakota (Peterka 1978). The Red River is part of the Hudson Bay Drainage (as is the Lake of the Woods area) and represents a significant extension of the known range of the Golden Redhorse (Figure 4).

Moxostoma erythrurum may have dispersed into the Hudson Bay watershed later than glacial Lake Agassiz. It probably invaded from the Mississippi River into the Red River after the recession of ice floes due to limiting water temperature (N. Mandrak, personal communication). Recent dispersal into the Red River may be restricted by a series of dams in North Dakota and Manitoba (Crossman and McAllister 1986) or it may be possible through the headwaters of the Minnesota and Red rivers during floods (Stewart and Lindsey 1983).

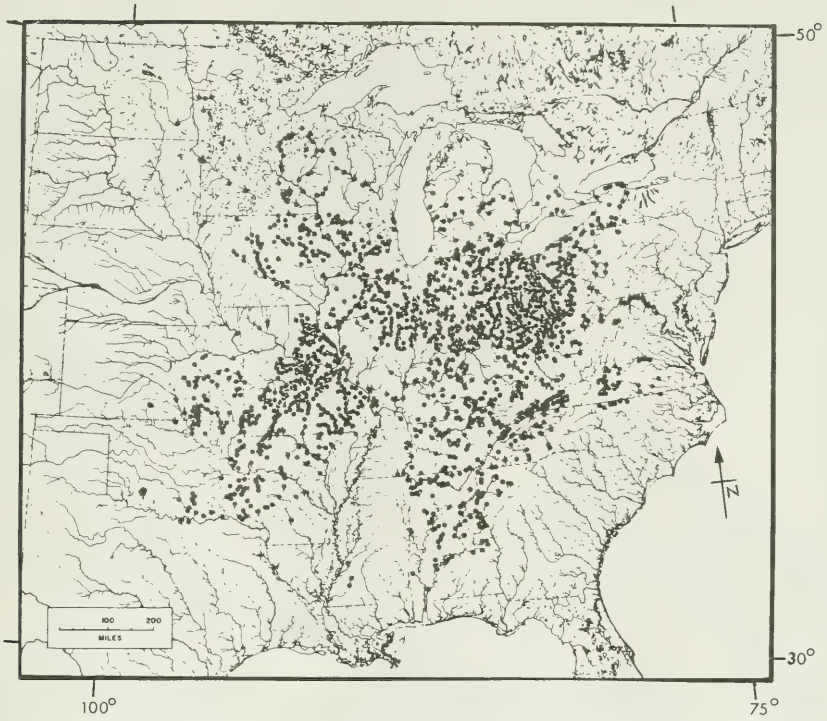

FIGURE 2. North American distribution of the Golden Redhorse, *Moxostoma erythrurum* [adapted from Lee et al. (1980)].

Protection

No specific protection other than that afforded by habitat sections of the Federal Fisheries Act exists in Canada. Since 1985, COSEWIC has suggested possibly assigning a rare status designation (Campbell 1985). It was listed as rare in Nebraska and South Dakota (Miller 1972). In Johnson's (1987) American Fisheries Society (AFS) list of protected fishes of the United States, and Canada it was designated as of special concern in both Manitoba and South Dakota.

Population Sizes and Trends

The actual population size of the Golden Redhorse has not been assessed in Canada. In southwestern Ontario, Golden Redhorse have been collected more or less continuously since the 1920s and continue to be found in small numbers to the present. Difficulty in identifying the different species of redhorses hampers attempts to assess population size. In the 1970s, a large area of southwestern Ontario was surveyed by the Ontario Ministry of Natural Resources (OMNR) as part of the Stream Inventory Program. Approximately 50% of all catalogued collections of Golden Redhorse were collected by OMNR during this period. Only small specimens were collected for positive identification, larger fish were returned to the water and clumped generally as redhorse suckers (G. Goodchild, Fisheries Branch, Ontario Ministry of Natural Resources, Toronto, Ontario; personal communication).

In northwestern Ontario, Golden Redhorse have apparently been collected for years in the oligotrophic part of the Lake of the Woods but in low numbers (V. Macins, personal communication), whereas Silver Redhorse are unknown from the Lake of the Woods although present throughout the surrounding area.

In the Red River, Manitoba, W. G. Franzin, Department of Fisheries and Oceans, Winnipeg, Manitoba; personal communication) suspects that the species is rare probably because of restrictions in the amount of preferred habitat.

It is an encouraging sign that the range of the Golden Redhorse in Canada appears to be expanding. Perhaps this is only indicative of increased survey efforts or better ability to distinguish Golden Redhorses from other redhorse species. Scott and Crossman (1973) felt that it was one of the few redhorses whose range did not seem to have been limited by habitat change.

In New York State, Golden Redhorses are thought to be increasing in abundance as it has

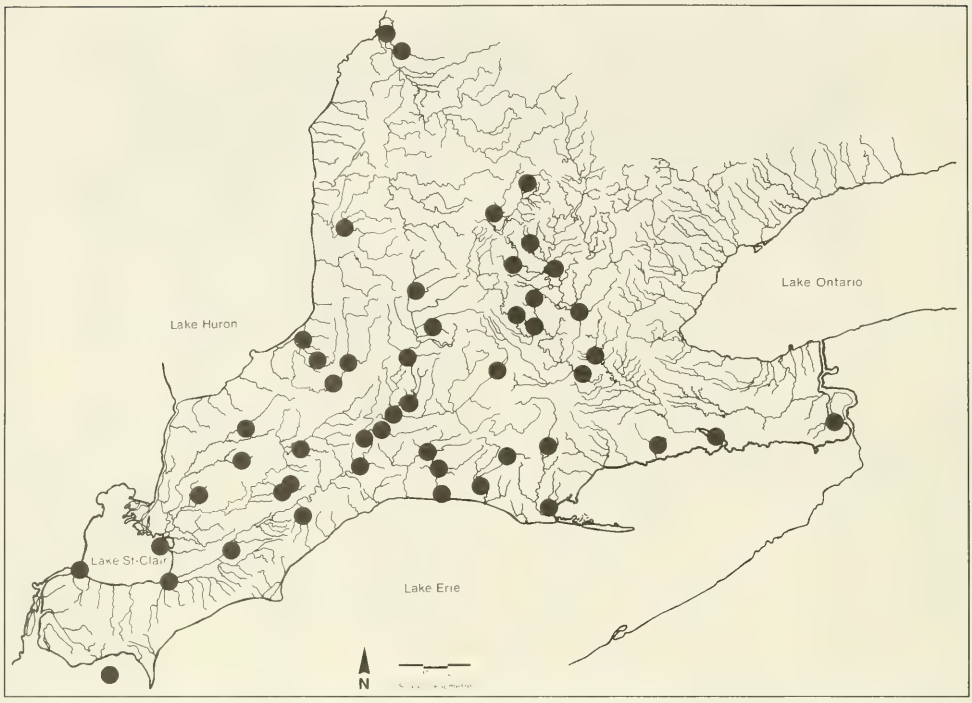

FIGURE 3. Distribution of the Golden Redhorse, *Moxostoma erythrurum*, in southern Ontario.

been collected more frequently in recent years (Smith 1985). Generally, in the United States, it appears to be faring well, often stated to be the most abundant redhorse in many states (Clay 1962; Cross 1967; Eddy and Underhill 1974; Pflieger 1975). In Ohio, the Golden Redhorse has been the most widely distributed and most abundant species of *Moxotoma* since 1920 (Trautman 1981). It is, however, intolerant of pollutants, continuous turbidity and rapid siltation.

Habitat

The Golden Redhorse does not have particularly specialized habitat requirements and is, apparently, able to tolerate a fairly wide spectrum of habitat conditions. It is better adapted to river habitats than to lakes and is typically found in small to large streams and rivers with varied substrate (Lee et al. 1980). Avoidance of streams with high gradients is indicated by the paucity of records from such streams (Trautman 1981). It is associated with streams having large permanent pools. In Pennsylvania, Cooper (1983) found adult Golden Redhorse in slow deep runs of moderate-sized rivers. Kott et al. (1979) collected both *Moxostoma duquesnei* and *Moxostoma erythrurum* in Ontario, at a site described as a stretch of swift-flowing shallow water over a gravel bottom ending in a one metre deep pool.

Although frequently collected with the Black Redhorse, the Golden Redhorse prefers slightly warmer waters with less current and is more tolerant of turbidity and intermittent flow (Pflieger 1975). In spite of its ability to withstand more siltation than most redhorse species, it has been eliminated from some streams by mine wastes (Clay 1962; Trautman 1981). According to Trautman (1981), it is seldom found in waters having an abundance of aquatic vegetation and only small numbers are present in larger lakes. On the other hand, Meyer (1962) remarks that the Shorthead Redhorse, *Moxostoma macrolepidotum*, is commonly found in lakes near the northern margin of its range and this seems to be the case for the Golden Redhorse as well. It has been found in Lake Erie (Trautman 1981), Lake St. Clair [ROM 1936, ROM 22892] and possibly the Lake of the Woods (V. Macins, personal communication) in the northern part of its range in Ontario.

In southwestern Ontario where it is reasonably abundant, it is apparently able to withstand some variation in water quality. Fluctuating turbidity levels, oxygen levels and temperatures are reported for the Thames River system by McAllister (1987), where the Golden Redhorse is commonly found. Rivers in southwestern Ontario are susceptible to these changes because it is a relatively flat, agricultural area.

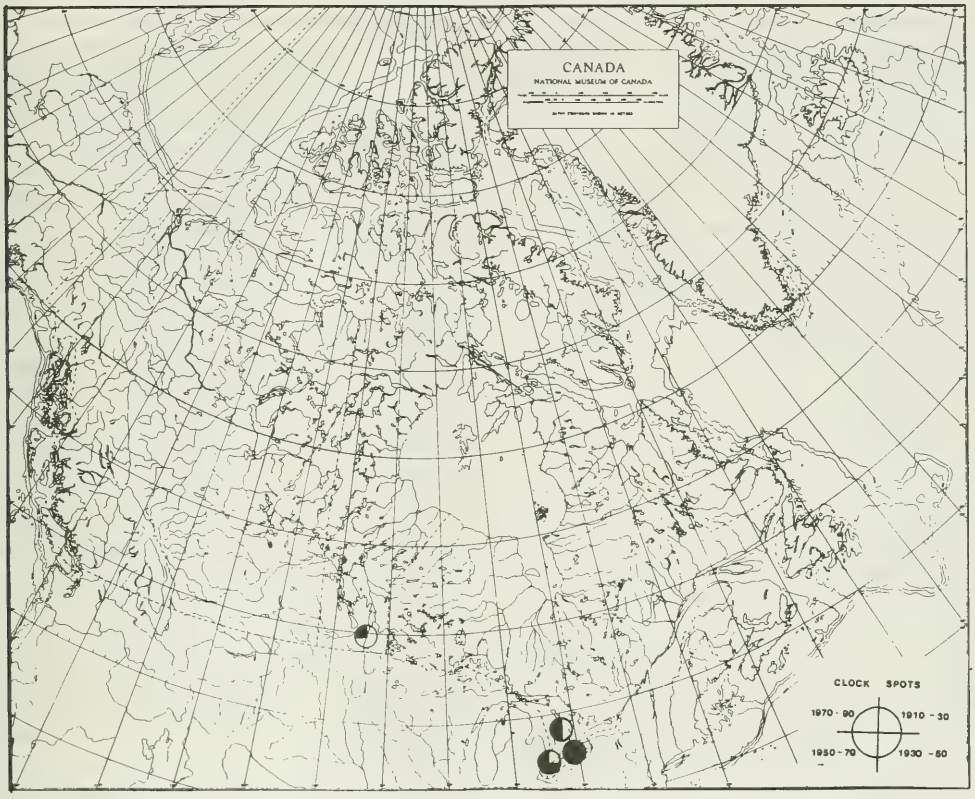

FIGURE 4. Canadian distribution of the Golden Redhorse, *Moxostoma erythrurum.*

Fluctuating water levels may have a detrimental effect on Golden Redhorse populations. Deacon (1961) found that in Arkansas, abundance of Golden Redhorse was directly related to stream conditions affected by drought, becoming scarce in the lower mainstream when flow increased. Meyer (1962) suggests that based on evidence presented by Hall and Jenkins (1953) and Finnell et al. (1956), the formation of reservoirs on rivers could have adverse effects on redhorse populations.

One factor involved in maintenance of Golden Redhorse populations may be the accessibility of smaller streams for spawning and nursery habitat (Harlan and Speaker 1956). Trautman (1981) also reports that Golden Redhorse ascend the smaller streams in spring. Yet, in a study of the seasonal movement of Golden and Black redhorses in Ohio, no significant differences were found between average distances moved in the spring as compared to the fall, nor were any mass seasonal movement patterns exhibited (Smith 1978).

Young Golden Redhorses have been described from varying habitats. Meyer (1962) and Larrimore et al. (1952) found young fish inhabitating slow-moving waters over soft-bottoms in areas near overhanging river banks, whereas Cooper (1983) found juveniles on riffle margins in moderate current. In contrast, Martin and Campbell (1953) found that, in Missouri, young Golden Redhorse inhabited the deeper, faster waters of streams near riffle areas.

The complexities of proper identification of *Moxostoma erythrurum,* combined with difficulties in determining optimum habitat, precludes making definitive statements regarding protection of suitable habitat in Canada.

General Biology

Reproductive Capability: No studies on the biology of this species in Canada have been reported. Descriptions of the reproduction of the Golden Redhorse in the United States are available but often conflicting.

Age and Growth: Maturity is reached between three and five, most commonly by age four (Meyer 1962; Cross 1967; Lee et al. 1980; Smith 1985). Although the oldest age attained is generally reported to be seven years, Curry and Spacie (1984) suggest that recent work on annulus formation and age determination in White Suckers (*Catostomus catostomus*) by Quinn and Ross (1982) may cast doubt on reliability of aging

catostomids older than age five, and perhaps they cease to form annuli after age seven. For age seven and older Black Redhorse, Bowman (1970) found that the percentage of scales with annuli completed by May decreased with increasing age, but he was able to age fish up to nine years.

Although Trautman (1979) gave a maximum size from Lake Erie as 660 mm (26 in) in length, and 2 kg (4.5 lb) in weight, he stated that the usual length was 279 to 457 mm (11 to 18 in). Meyer (1962) found they reached an average length of 84 mm (3.3 in) by age one and 488 mm (19.2 in) by age seven, whereas in Oklahoma they reached a maximum size of 625 mm (24.6 in) [Scott and Crossman 1973]. In Missouri, they averaged 79 mm (9.1 in) at the end of their first year, and about 150 mm (9.9 in), 218 mm, 272 mm, 310 mm at the end of each succeeding year, with an average life span of six to seven years. Few fish over 11 years of age were reported. Meyer (1962) found no difference in growth rates between sexes and found that most of the growth occurred in late July, August and early September.

Spawning: Golden Redhorses spawn in spring, usually in May or early June and later than other redhorses in the same area, (Scott and Crossman 1973). In Iowa, spawning occurs after water temperatures rise to greater than 16°C (60°F) [Meyer 1962], but in Kansas, temperatures of greater than 22°C (70°F) have been noted (Cross 1967). Both fall within the range of 17° to 22°C given by Lee et al. (1980).

Spawning lasts for only a short period. Males are generally observed at the spawning sites prior to the arrival of the females, apparently defending territories. Sex ratios were found to be 75 males to 37 females indicating the brevity of the females stay (Mayer 1962). Sex ratios at other times of the year were 1:1. Non-adhesive eggs are broadcast over gravel riffles and abandoned (Cooper 1983). Meyer (1962) estimated that the average number of eggs per female is 6100 to 25 390, but estimates ran as high as 35 000 in Ohio (Carlander 1950).

Depth or flow may be a critical factor in the selection of spawning sites as suggested by Curry and Spacie (1984). They observed that spawning did not take place until stream levels had dropped and velocity decreased. Smith (1977) reported stream velocities of 0.9 to 1.2 $m.s^{-1}$ during spawning of Golden Redhorse in Clear Creek, Iowa. Reproductively active males usually occupy shallow water with moderate current (Cross 1967). Spawning in shallow water up to 0.6 m deep is reported by various authors (Reighard 1920; Meyer 1962; Eddy and Underhill 1974).

Species Movement: One of the most controversial aspects of the biology of the Golden Redhorse is the disagreement over whether or not the species migrates to any appreciable degree. Scott and Crossman (1973) describe it as being sedentary, remaining in or near the same pool with occasional marked downstream movements. Short migrations upstream have also been frequently observed (Cross 1967; Bowman 1970; Smith 1977; Cooper 1983). Trautman (1981) states that the Golden Redhorse has a highly migratory nature. Yet, Meyer (1962) and Smith (1978) found no evidence for movement. Individuals marked by Deacon (1961) in Kansas during stable water levels were recaptured in areas of original capture and release. Cross (1967) also found the Golden Redhorse to be sedentary except during periods of fluctuating water levels. Gerking (1953) states that the Golden Redhorse does not ascend small streams in Indiana unless they are near their home territory.

Studies undertaken by Curry and Spacie (1984) may explain conflicting observations on spawning movements that have been reported. They found that there was an age/size differential in the use of tributaries. Larger adults do not apparently expend the energy to move upstream where smaller/younger adults are more common. Segregation of spawning groups by size acts to distribute the competitive advantage for the Golden Redhorse.

Further studies might be undertaken to determine if the degree of migration is related to preferred habitat regarding depth and rate of flow for various age/size groups. Stream alterations that affect temperature, depth, flow regimes, and fish movement would tend to have an impact on populations. For this reason, the construction of dams or reservoirs could have debilitating effects on populations.

Adaptability/Behaviour: The Golden Redhorse feeds primarily on small molluscs, crustaceans, insects, detritus and algae (Lee et al. 1980). Cooper (1983) describes it as a benthic feeder. Results of a Iowa study to determine principal foods for redhorse above four inches long are listed: immature chironomids (91%), immature Ephemeroptera (62%), and immature Trichoptera (18%) [Meyer 1962]. No differences in food habits were found between Golden Redhorse, Silver Redhorse and Shorthead Redhorse. Significant differences in the major groups of food consumed by Golden Redhorse were found between age groups and different populations (Brown 1984).

The following group of parasites were listed by Hoffman (1967): Protozoa, Trematoda, Nematoda, Acanthocephala, leeches.

Since the Golden Redhorse is still considered common in most areas of its range in the United States, it is probably reasonably tolerant of human disturbance. Its continued existence in Canada

may be more tenuous due to being at the northern extent of its range.

Limiting Factors

There is no evidence to suggest that the Golden Redhorse populations are declining in Canada. It is difficult to determine whether the broader distribution of the Golden Redhorse has resulted from true range extensions or because of asystematic sampling and difficulties in identifying species of redhorse suckers.

Although apparently more tolerant to habitat alterations than the Black Redhorse, it does seem to be susceptible to changes that affect stream depth or velocity of flow. Any damming or reservoir development on Golden Redhorse streams would have potentially adverse effects. In Ontario, several dams on the Grand and Thames rivers have reduced the amount of suitable habitat for the Black Redhorse (Parker and Kott 1987). Doubtless, these dams have had detrimental effects on Golden Redhorse populations as well.

The area of southwestern Ontario occupied by the Golden Redhorse is rural, characterized by large areas cleared for agricultural use. The degree of impact from agricultural practices — pesticides, siltation, stream channelizations, irrigation, and reservoirs is uncertain, but bound to have a negative effect on Golden Redhorse populations.

Angling probably has a negligible effect on Golden Redhorse populations. The Golden Redhorse is not sought after in Canada, but it is taken incidentally on hook and line with natural bait.

There is some recreational fishing for the Golden Redhorse in the United States. In Kansas, the Golden Redhorse had long supported a sport fishery (Cross 1967). Due to local abundance in Pennsylvania, it is often taken by anglers and often preferred over other suckers for food (Cooper 1983). In other states such as Iowa, it is not a favoured species but they are taken occasionally from streams (Harlan and Speaker 1956).

Scott and Crossman (1973) considered redhorse suckers to be commercial species of some importance in some areas. Since all species of redhorses are generally marketed as suckers or mullet, it is difficult to appraise the contribution to the catch of one species. However, they felt that both size and stream habitat precluded any significant entry into the commercial catch by the Golden Redhorse.

Both young and adults of this species probably do not compete for food or space with more valued species (Scott and Crossman 1973). Meyer (1962) found no difference in food habits between the Golden, Silver, and Shorthead redhorse. Although these species often co-exist in the same streams, slight variations in the preferred areas occupied may diminish the amount of competition for food.

Except for young fish, Golden Redhorses are not likely subject to significant predation. Predation on adults is probably limited by their size and the faunal composition of their habitat (Scott and Crossman 1973).

Special Significance of the Species

The Golden Redhorse, belongs to the genus *Moxostoma*, one of the most perplexing groups of North American fishes. Despite numerous species and large size, very little information is available on life history. The uncertain systematic position of the species is due to the few interspecific differences exhibited in meristic features (Scott and Crossman 1973).

In Canada alone, there are seven species of *Moxostoma*. Because of problems in distinguishing between these species, capture records are unreliable. For this reason, and due to sporadic sampling, it is difficult to determine whether populations are stable or declining. Three species of redhorse are considered threatened or rare in Canada. *Moxostoma carinatum*, the River Redhorse, is considered rare; the Black Redhorse and *Moxostoma hubbsi*, the Copper Redhorse, are considered threatened (Parker and McKee 1984; McAllister et al. 1985; Parker and Kott 1987). Canadian populations are apparently contiguous with those in the United States, but are at the northern limit of the range of the Golden Redhorse. The species is of some minor importance as a bait fish and to sport and commercial fishermen.

Evaluation

Whether recent records updating the distribution of the Golden Redhorse are a result of recent range extensions or of more intensive sampling is difficult to judge. No population studies have been done in Canada but collection records indicate it is still present throughout most of its range in southwestern Ontario. Status of populations in Manitoba have not been ascertained. While populations of the Golden Redhorse do not appear to be under immediate threat, the species is vulnerable to changes in depth, rate of flow, excessive turbidity and pollution.

Until more information is available on population trends, the status of the species in Canada is difficult to ascertain. However, existing populations appear to be stable and there is no requirement for COSEWIC status at this time.

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Status of Dall's Porpoise, *Phocoenoides dalli*, in Canada*

THOMAS A. JEFFERSON

Marine Mammal Research Program, Texas A & M University, P.O. Box 1675, Galveston, Texas 77553-1675

Jefferson, Thomas A. 1990. Status of Dall's Porpoise, *Phocoenoides dalli*, in Canada. Canadian Field-Naturalist 104(1): 112–116.

Dall's Porpoise, *Phocoenoides dalli*, is one of the most commonly sighted cetaceans throughout its range in temperate waters of the North Pacific Ocean and surrounding seas. Dall's Porpoises are common both offshore and in deep inshore waters of British Columbia. There appear to be few serious conservation problems in the eastern Pacific at present, although little is known of the behaviour and ecology of this species. Probably the major threat facing this species in Canada is environmental contamination by such substances as organochlorines and heavy metals. Much more research is needed before these threats can be properly assessed but, in the meantime, a conservative approach to porpoise management is suggested.

Le marsouin de Dall, *Phocoenoides dalli*, est l'un des cétacés les plus couramment aperçus dans toute son aire de distribution en eaux tempérées de l'océan Pacifique nord et des mers viosines. Le marsouin de Dall est commun tant dans les eaux du large que dans les eaux côtières profondes de la Colombie-Britannique. Actuellement, la conservation de cette espèce présente peu de problèmes importants dans l'est du Pacifique, bien qu'on connaisse peu de chose de son comportement et de son écologie. La contamination de l'environnement par, notamment, les organochlorés et les métaux lourds constitue probablement le principal danger pouvant menacer l'espèce au Canada. Une évaluation adéquate de ce genre de dangers nécessiterait des recherches beaucoup plus importantes et l'on propose, entre temps, de procéder avec prudence à la gestion de ce marsouin.

Key Words: Dall's Porpoise, *Phocoenoides dalli*, cetaceans, British Columbia, status.

Dall's Porpoise, *Phocoenoides dalli* (True 1885), despite being a commonly-sighted species in the North Pacific, is rather poorly known in most aspects of its ecology and population biology. The published literature on this species has recently been reviewed (Jefferson 1988), and therefore this report focuses only on information relevant to its status in British Columbia.

Dall's Porpoise is the largest member of the porpoise family (Phocoenidae), growing to lengths of about 220 cm and weights of 200 kg (Leatherwood et al. 1982). These animals are extremely robust, with small heads and small appendages (Figure 1). The wide-based triangular dorsal fin is slightly recurved at the tip, and the caudal peduncle is strongly keeled, especially in adult males (Jefferson 1990).

The colour pattern is diagnostic. A ventrally-continuous white patch extends up on both flanks and forward to the level of the dorsal fin on the predominantly black body. White to light gray areas occur on the upper half to two-thirds of the dorsal fin, and the rear borders of the flukes. This "frosting" is not present on newborns. There appear to be several colour morphs, including gray, all-black, and all-white forms. A discrete population off the Pacific coast of Japan has a larger flank patch (this colour morph is called *truei*-type, as opposed to *dalli*-type; Kasuya 1982).

Distribution

Phocoenoides dalli is a North Pacific endemic, being found from northern Baja California, Mexico, north to the southern Chukchi Sea, and south to southern Japan (Figure 2). The species is only common between 32°N and 62°N in the eastern North Pacific (Nishiwaki 1967; Morejohn 1979).

Off the west coast of Canada, Dall's Porpoises are found mostly over the Continental Shelf and slope, but also more than 2400 km from shore (Pike and MacAskie 1969). They are seen year-round in the deeper inshore waters of British Columbia (Leatherwood et al. 1982).

There are 15 published specimen records and over 300 sighting records from British Columbia (Cowan 1944; Scheffer 1949; Pike and MacAskie 1969; Jefferson 1987; Baird et al. 1988) Off the coast of Canada, Dall's Porpoises are found mostly over the continental shelf and slope, but occasionally more than 2400 km from shore (Pike and MacAskie 1969). They are seen year-round in the deeper inshore waters off British Columbia, such as Hecate Strait, Laredo Channel, Queen Charlotte Sound, Goletas Channel, Queen Charlotte Strait, Johnstone Strait, and Strait of Juan de Fuca (Cowan 1944; Pike and MacAskie 1969; Leatherwood et al. 1982; Jefferson 1987).

*Reviewed and accepted by COSEWIC 11 April 1989 – no designation required.

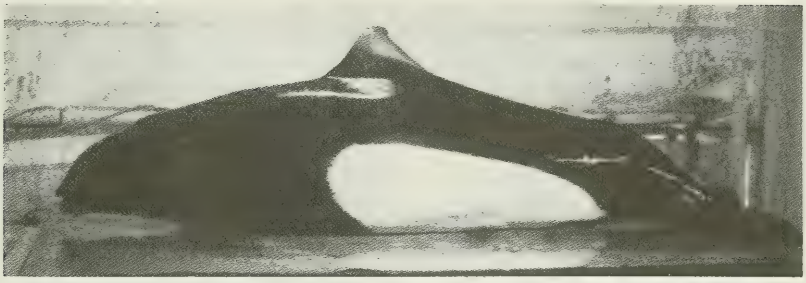

FIGURE 1. Adult Female Dall's Porpoise, *Phocoenoides dalli* (photograph by the author).

Protection

Dall's Porpoise is protected in Canadian waters under the 1982 Cetacean Protection Regulations of the Fisheries Act of Canada of 1970. In United States waters, primary protection is provided by the Marine Mammal Protection Act of 1972. International protection measures include listing in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which regulates international trade.

Population Size and Trends

The population status of animals in the eastern North Pacific is not known, and there are no abundance estimates for British Columbia. Leatherwood et al. (1982) called *Phocoenoides dalli* the most abundant porpoise north of Vancouver Island. The entire North Pacific Ocean and Bering Sea population is estimated to be 1.4 to 2.8 million animals (Jones et al. 1987). The population trend is unknown, but because there is no evidence of major mortality, it is assumed to be relatively stable in the eastern Pacific. The western Pacific and Bering Sea stocks are heavily exploited and some may be at risk (Jones et al. 1987; Perrin 1988).

Habitat

The species is widespread along the British Columbia coast, and is quite common both inshore and offshore. Cowan (1944) suggested that in inshore areas, Dall's Porpoises select open-ended channels with strong currents. The primary habitat is cool ($< 17°C$), deep (> 180 m), continental shelf and slope waters (Jefferson 1988). Morejohn (1979) suggested that movements are mainly due to availability of prey, which consists of various species of squid and small schooling fishes. Many different prey species are known from throughout the range, and the Dall's Porpoise is thought to be an opportunistic feeder (Stroud et al. 1981), although the stomachs of four specimens from British Columbia contained only Pacific Herring, *Clupea harengus* (Cowan (1944). There is no evidence of significant habitat change in British Columbia.

General Biology

Reproductive Capability: Very little information is available on Dall's Porpoise reproduction in the eastern North Pacific. There is apparently a very strong summer calving peak (as in the rest of the range) in the months of June through August, and a smaller peak in March (Jefferson 1989).

Most information comes from the western Pacific, where large-scale fishery interactions provide large samples for analysis. *Dalli*-type males become sexually mature at an age of 4 to 6 years and a length of 180 to 186 cm, and females

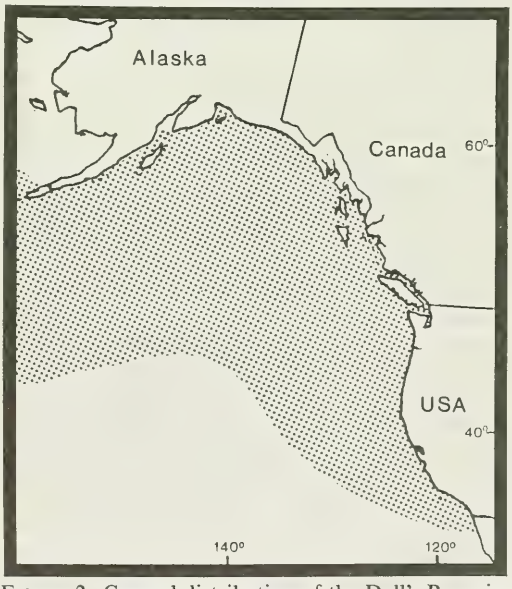

FIGURE 2. General distribution of the Dall's Porpoise in the eastern North Pacific.

at 3.5 to 4.5 years and 174 to 177 cm (Kasuya and Shiraga 1985; Jones et al. 1987; Miyazaki 1987). *Truei*-type animals become mature at body lengths about 12 to 17 cm greater than these (Kasuya 1978; Kasuya and Shiraga 1985). Most females appear to have an annual reproductive cycle (Kasuya and Jones 1984; Jones et al. 1987). Gestation lasts about 10 to 11 months (Jones et al. 1983); and the lactation period is unknown, but it is thought to be very short, perhaps 2 to 4 months (Newby 1982).

Species Movement: Dall's Porpoises in the eastern North Pacific, although present throughout their range year-round, tend to have inshore and southern shifts in abundance for the winter, and offshore and northern shifts for the summer (Leatherwood et al. 1982). They are present both inshore and offshore in British Columbia all year, although there seems to be an offshore shift in abundance for the summer (Pike and MacAskie 1969; Leatherwood et al. 1982).

Behaviour/Adaptability: These animals are avid bow-riders, and are thought to be among the fastest swimming small cetaceans. When bow-riding or moving quickly they produce a distinctive rooster-tail splash. Porpoises not reacting to vessels often surface in a slow roll, with no splash. At these times, the deepened peduncle is visible above the surface. This type of surfacing seems to be predominant in inshore waters (Jefferson 1987; Miller 1988a). Dall's Porpoises rarely breach or indulge in other aerial behaviour.

Porpoises are attracted to vessels in both inshore and offshore waters, especially to bow-ride, but they sometimes avoid vessels as well (Withrow et al. 1985) In particular, cow/calf pairs often avoid ships (Kasuya and Jones 1984).

Groups are generally small (less than 10 animals) and fluid, and are composed of very small subgroups which may aggregate at times, especially for feeding (Miller 1988b). Large aggregations of up to several thousand are occasionally seen (Scheffer 1950).

The degree of habitat specialization has not been well studied in this species. Inshore calving areas have been proposed for both major study areas in Puget Sound, Washington and Johnstone Strait, British Columbia (Jefferson 1987; Miller 1988a), but young calves are seen offshore as well, especially in the western Pacific (Kasuya and Jones 1984; Kasuya and Ogi 1987). Feeding presumably occurs throughout the range.

Limiting Factors

Killer Whales, *Orcinus orca*, and to a lesser extent, large sharks, are potential predators but the degree of predation is unknown (Pike and MacAskie 1969; Morejohn 1979; Newby 1982). Dall's Porpoises are rarely preyed upon by resident whales in British Columbia, but transient Killer Whales attack marine mammals (Bigg et al. 1987). There is little evidence that sharks regularly take healthy animals (Dall's Porpoises may swim too fast for most sharks), although one may speculate that they may weed-out sick or injured porpoises that are less able to avoid them.

Parasite infestations are common and often extensive in this species (Walker 1975), but the role they play in natural mortality is unknown. Disease factors have not been adequately studied in *Phocoenoides dalli*.

Human disturbance or disruption of activities is not thought to be a serious problem at present. As noted by Miller (1988a), these animals generally have complete control over encounters with boats, and it is indeed nearly impossible to follow them if they do not want to be followed. Heavy sustained vessel traffic in major feeding or breeding areas, however, could potentially disrupt activities or cause abandonment of the area. Future oil and gas exploration activities could pose a threat to this species, although the risk is still largely unknown (Geraci and St. Aubin 1980; Würsig 1990). One can speculate that a major oil spill in a critical feeding area could be harmful.

Although some incidental morality occurs due to fishing operations, no major fishery conflicts are known in Canada. Small numbers have been reported to be captured in gillnets and trawl nets (Everitt et al. 1979; Jefferson 1987; R. W. Baird, Victoria, British Columbia; personal communication), and 58 were taken in 1987 in the experimental squid driftnet fishery, but this fishery has since been discontinued (Baird et al. 1988). The species has a tendency to entangle in gillnets, however, and the possibility of undocumented problems exists.

The largest potential threat to this species in Canadian waters may be environmental pollution by human activities. Little work has been done in the eastern Pacific, but Japanese scientists have recently explored levels of organochlorines and heavy metals in porpoises from the western Pacific. Small cetaceans were found to be poorly equipped to metabolize PCBs (Tanabe et al. 1988). High PCB and DDE levels can result in decreased testosterone levels, possibly impairing reproduction (Subramanian et al. 1987b). Perhaps most disturbing was the discovery that excretion of pollutants by females occurs mainly through parturition and lactation (Subramanian et al. 1987a). Thus, it is possible that young Dall's

Porpoises in some areas are starting their lives with already high levels of environmental contaminants.

Special Significance of the Species

Dall's Porpoises are known to most people who frequent the deeper coastal waters of the western United States and British Columbia. Although they support no industry of their own, Dall's Porpoises often delight passengers on whale-watching and nature cruises along the west coast. Their bow-riding antics never cease to thrill those lucky enough to see them, and these cruises would certainly lose some of their appeal without them.

The species normaly feeds on small schooling fishes and squids that are not highly prized by sport and commercial fishermen. Because it is an upper level carnivore that accumulates pollutants, it might be used as a biological indicator of the health of local ecosystems (Tanabe et al. 1983).

Evaluation

There is no evidence that Dall's Porpoise populations in British Columbia are being depleted at present. Although several western Pacific populations may be depleted, *Phocoenoides dalli* is considered to be common in Canada. However, there is a lack of information on potential threats, and until more is known, a conservative management approach should be taken.

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Status of Blainville's Beaked Whale, *Mesoplodon densirostrus*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of Blainville's Beaked Whale, *Mesoplodon densirostris*, in Canada. Canadian Field-Naturalist 104(1): 117-120.

Blainville's Beaked Whale, *Mesoplodon densirostris*, is widely, if thinly, distributed in tropical and subtropical waters and occurs irregularly off the east coast of Canada. It has yet to be reported from the west coast, although one stranding has been reported from northern California. The species appears to be more pelagic than other ziphiids and of no commercial interest. They are rare in Canadian waters.

La baleine à bec de Blainville, *Mesoplodon densirostris*, est une espèce cosmopolite, quoique rare, qui fréquente les eaux tropicales et subtropicales. Elle est parfois présente au large de la côte est du Canada mais elle n'a pas encore été signalée sur la côte ouest quoiqu'on ait observé un individu échoué sur la côte nord de la Californie. L'espèce semble plus pélagique que les autres Ziphiidés et ne porte aucun intérêt commercial. Elle est rare dans les eaux canadiennes.

Key Words: Blainville's Beaked Whale, *Mesoplodon densirostris*, Dense Beaked Whale, baleine à bec de Blainville, Cetacea, Ziphiidae, *Mesoplodon*, status, Canada.

Blainville's Beaked Whale, *Mesoplodon densirostris* (de Blainville 1817), is of medium length averaging 4.5 to 5 m and reaching a weight of about 1000 kg. The species has the spindle shape typical of the ziphiids, but can be distinguished by the shape of the head (Figure 1).

The mouth has a distinctive shape formed by the two laterally compressed teeth which give the mouth a high, arched contour, especially in adult whales (*see* Watson 1981; Leatherwood et al. 1982). The teeth, in males, may be up to 20 cm in height but the root, and much of the crown, are enclosed in heavy bone [34% denser than elephant ivory (de Blainville 1817)] which gives rise to the common name Dense Beaked Whale and the specific name *densirostris* (Watson 1981). This feature makes the species easy to distinguish from other ziphiids. In addition, the head may be flattened in front of the blowhole, providing another aid to identification (Leatherwood and Reeves 1983).

The species has small flippers and a small dorsal fin situated about midway on the trunk, and it is usually pointed and triangular, but may vary in shape. There may be a slight convexity on the rear edge of the flukes, but a median notch is usually absent (Watson 1981; Leatherwood et al. 1982; Leatherwood and Reeves 1983).

Blainville's Beaked Whales are bluish grey to dark grey dorsally, being slightly lighter in colour ventrally. The anal area may be considerably lighter and males in particular have whitish or pink blotches over much of the body, thought to be caused by "cookie-cutter" sharks or some other type of epizoic or parasitic fish (Leatherwood et al. 1982). Many males show heavy scarring which may be the result of intra-specific fighting (*see* Heyning 1984).

Distribution

Mesoplodon densirostris is the only species of the genus which crosses the equator (Davies 1963). The species is more widely distributed (Figure 2) than any other member of the genus. Blainville's Beaked Whales have been reported from the Indian, North Atlantic and North and South Pacific Oceans (Moore 1966). Although not as yet recorded in the South Atlantic, Moore (1966) predicts that it will be found there. The species strands more often on oceanic islands than on continental coasts, leading Moore (1966) to suggest a pelagic distribution, further offshore than the other *Mesoplodon* species.

The species appears to be relatively uncommon along the west coast of North America with only one recorded stranding on the northern California coast (Leatherwood et al. 1982). On the east coast, occasional, single strandings have been recorded from Nova Scotia south to Florida, the Bahamas and the Gulf of Mexico (Moore 1966; Leatherwood and Reeves 1983).

Protection

International: Blainville's Beaked Whale is listed under Appendix II to the Convention on International Trade in Endangered Species

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

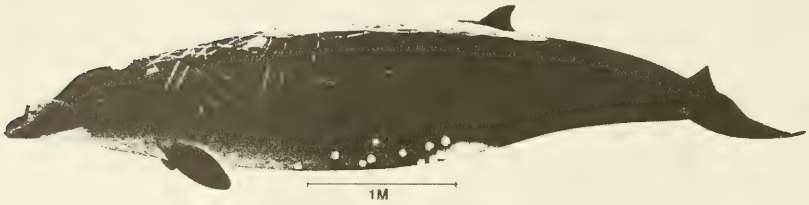

FIGURE 1. Blainville's Beaked Whale, *Mesoplodon densirostris* (drawning courtesy of Canada Department of Fisheries and Oceans).

(CITES) of which Canada is a party. Such listing requires regulation of trade in live specimens, parts and derivatives by those countries party to the Convention. Trade must be covered by an appropriate export permit issued by the government of the exporting country, before entry to another party nation is permitted. There are currently over 100 nations party to the Convention.

The species is also listed as being Indeterminate in Status in the Red Data Book (Goodwin and Holloway 1972), and Mitchell (1975a: 13) has accepted their listing in placing the species in the category of a species not generally known to have been taken, or to be presently captured, except for scientific purposes, uniquely or accidentally.

National: This species, along with other members of the genus, is protected by general legislation in several countries but no specific measures are known.

All cetaceans are protected in Canadian waters under the Fisheries Act of 1987 (and amendments thereto) and the Cetacean Protection Regulations promulgated under the Act. In the United States, general protection is provided under the Marine Mammals Protection Act of 1972 and the Endangered Species Act.

Population Sizes and Trends

No reliable information is available on population sizes and trends for this species. Live individuals are rarely observed at sea, but have been photographed near Hawaii (Leatherwood et al. 1982). The more pelagic distribution of this species, as compared to other members of the genus, may indicate that they would be less subject to the coastal small whale fisheries which still exist, particularly in Japan. The effects of exploitation on numbers may therefore be regarded as negligible. Although, apparently not abundant where it is known (Mitchell 1975a), the wide distribution suggests that the overall status of the species is secure.

Habitat

Little information on habitat preferences, etc. is available, as the species is known mainly from strandings. These whales appear to be creatures of the open seas. Strandings have been recorded more often from oceanic islands than on continental coasts (Moore 1966; Leatherwood et al. 1982). The species appears to have a preference for tropical and sub-tropical waters as the distribution seems, for the most part, to extend no farther north and/or south of the equator than 35° latitude. The distribution may be limited by water temperatures, currents and/or distribution of the prey. Their occurrence in the North Atlantic as far north as Nova Scotia (45° N) may be related to the Gulf Stream (Watson 1981).

General Biology

Nothing is known of the reproductive behaviour or life history of the species. The length at birth may be between 1.9 to 2.6 m (Leatherwood and Reeves 1983). Attempts to age individuals reading growth layers in the teeth were inconclusive (Mitchell et al. 1981), but age at maturity appears to be about nine years (Leatherwood and Reeves 1983).

Sound recordings of stranded live animals have been made (Poulter 1968; Caldwell and Caldwell 1971), and members of the species apparently produce sounds described as roars, lowing, and sobbing and groans. Caldwell and Caldwell (1971) described chirps and whistles distinctly pulsed with frequencies from 1 to 6 kHz.

The diet appears to consist of squid and pelagic fish (Watson 1981; Leatherwood et al. 1982).

The species is usually seen in small groups of less than 10 individuals (Watson 1981; Leatherwood et al. 1982) which may represent family units. Blainville's Beaked Whales usually strand singly and are often alive when found (Moore 1966; Leatherwood et al. 1982). A few sightings have been made at sea; the species seems to be shy and has a very indistinct blow (Leatherwood et al. 1982). They appear to be slow swimmers and dive for periods of 20 minutes or longer (Watson 1981; Leatherwood et al. 1982).

Limiting Factors

None Known. The species has apparently not been subject to exploitation by small whale fisheries, and because of its pelagic nature, these are not likely

FIGURE 2. Distribution of Blainville's Beaked Whale.

to be a threat in the future. Since small whale fisheries are opportunistic and indiscriminate as to species, they tend to be multispecies fisheries. In such fisheries one may think that a falling catch per unit effort would not influence future catch effort. However, many of the species in such fisheries are rare and it cannot be assumed that any future exploitation would, in the longterm, be inconsequential (*see* Mitchell 1975b). At present, the species is probably inherently protected by its rarity and pelagic habits.

Special Significance of the Species

Most of what is known of ziphiids in Canadian waters comes from the few specimens stranded here. Blainville's Beaked Whale has not as yet been recorded from British Columbia but is known from Nova Scotia. The species is not known to have been taken by commercial whalers and probably not by coastal fisheries because of its pelagic habits. It is doubtful that the species or parts or derivatives would show up in international trade as there is no demand.

Blainville's Beaked Whale could be confused with Cuvier's Beaked Whale (*Ziphius cavirostris*) where the ranges overlap. Identification requires an expert.

Evaluation

Blainville's Beaked Whales are medium-sized cetaceans which are widely dispersed in tropical and sub-tropical waters. Mitchell (1975a,b) has indicated that most species of the genus are probably not abundant and that even moderate exploitation could impact negatively on existing populations. The species is not known from British Columbia and is only rarely seen on the east coast.

Given the above, and the fact that Canadian distribution is on the periphery of the range, the species would appear to be rare in Canadian waters. As it is not under any threat in Canada there is no reason to consider a COSEWIC status designation for the species at this time.

Acknowledgments

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Status of Hubbs' Beaked Whale, *Mesoplodon carlhubbsi*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of Hubbs' Beaked Whale, *Mesoplodon carlhubbsi*, in Canada. Canadian Field-Naturalist 104(1): 121–124.

Hubbs' Beaked Whale, *Mesoplodon carlhubbsi*, is a rare member of the North Pacific fauna. The species is known from 31 stranded specimens and one possible live sighting. Most strandings have been along the North American coast from Prince Rupert, British Columbia to La Jolla, California. Four strandings are recorded from Ayukawa, Japan. The species is not known to have been, or to be, of interest to commercial fisheries and is probably protected by its rarity and occurrence in less frequented (by man) waters of the North Pacific.

La baleine à bec de Hubbs, *Mesoplodon carlhubbsi*, est une espèce rare de la faune du Pacifique Nord. On connaît l'espèce d'après 31 spécimens échoués et une observation possible d'un spécimen vivant. La plupart des échouements se sont produits le long de la côte de l'Amérique du Nord, depuis Prince Rupert, en Colombie-Britannique, jusqu'à La Jolla, en California. On signale par ailleurs quatre spécimens échoués à Ayukawa, au Japon. L'espèce n'est pas reconnue pour avoir présenté ou pour présenter un intérêt pour la pêche commerciale et est probablement protégée en raison de sa rareté et de sa présence dans les eaux moins fréquentées (par les hommes) du Pacifique Nord.

Key Words: Hubbs' Beaked Whale, *Mesoplodon carlhubbsi,* Arch-beaked Whale, baleine à bec de Hubbs, Cetacea, odontocetes, Ziphiidae, beaked whales, *Mesoplodon.*

Hubbs' Beaked whale, *Mesoplodon carlhubbsi* Moore 1963, is a toothed whale of the family Ziphiidae and is typical of the genus in size and shape (*see* Watson 1981). Also known as the Arch-beaked Whale, this small ziphiid was not described as a separate species until the 1960s (Moore 1963). The species is similar enough to *Mesoplodon stejnegeri* (Stejneger's Beaked Whale) to be confused with it. It is known mainly from stranded specimens (Mead et al. 1982).

These are medium-sized beaked whales (Figure 1) with maximum length estimated at about 5.3 m and a maximum weight of about 1500 kg (Watson 1981; Mead et al. 1982). The shape is similar to that of other ziphiids with a large thorax and small head and tail. There is a prominent pair of vertical throat grooves; the flippers are thin and elongated and can be depressed in "flipper pocket" repressions in the body wall posterior to each flipper. There is no median notch on the flukes which are otherwise similar to those of most medium-sized whales (Watson 1981; Mead et al. 1982).

The most striking external features of the species is the pigmentation of the head, particularly in adult males. The white rostrum contrasts with the nearly black body, and on the mandible, the posterior edge of the white patch parallels the posterior edge of the erupted tooth (Mead et al. 1982; Heyning 1984). There is less contrast in females and subadults but the area is generally lighter than the remainder of the head. The extent of the lighter pigmentation may be age related (Mead et al. 1982). The rest of the body is dark grey to black but the ventral surface may be lighter in subadults and females. The bodies of adult males tend to be marked by uneven linear scars which are thought to result from intra-specific fighting (Heyning 1984). As in all *Mesoplodon* species, the teeth erupt only in adult males and the rostum is strongly constricted by the projecting pair of mandibular teeth (Mead et al. 1982) which are larger than in other ziphiids (Heyning 1984).

Distribution

Most of the information concerning distribution comes from the relatively few (31) recorded strandings (*see* Mead et al. 1982). The species seems to be restricted to the North Pacific (Figure 2) and most strandings (27) have been along the west coast of North America from San Diego, Califoria (33° N) to Prince Rupert, British Columbia (54° N). This may be the northern limit as no strandings have been reported north of 54° N, but there are abundant records of *Mesoplodon stejnegeri* north of this limit. The southern limit may be the product of a general lack of information, as no strandings have been recorded

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

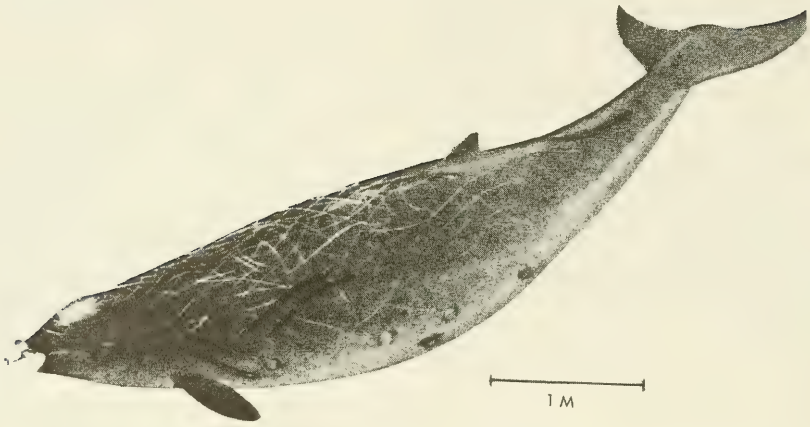

FIGURE 1. Hubbs' Beaked Whale, *Mesoplodon carlhubbsi* (redrawn and adapted from Watson 1981).

from Central America south to the equator (Mead et al. 1982). Pike and MacAskie (1962) report three strandings along the British Columbia coast and Mead et al. (1982) recorded four others. One sighting of a small whale by Hubbs (1946) off La Jolla, California, is the only posible sighting of a live animal.

The range appears to extend west to Japan where the species has been recorded from the northeast coast of Honshu at about 38° N latitude (Mead et al. 1982). The range appears to be south of that of Stejneger's Beaked Whale and north of that of *Mesoplodon ginkgodens,* the Ginkgo-Toothed Beaked Whale (Watson 1981).

Protection

International: Mesoplodon species are included in Appendix II of the Convention on International Trade in Endangered Species (CITES). No other international agreements refer to the genus. The species is listed as 'Indeterminate' in the Red Data Book (Goodwin and Holloway 1972).

National: The genus is protected by general legislation in several countries but no specific provisions are known. In Canada, general protection is accorded under the Fisheries Act and the Cetacean Protection Regulations which prohibit commercial whaling. In the United States, general protection is accorded under the Marine Mammal Protection Act of 1972 and the Endangered Species Act.

Population Sizes and Trends

Known only from 31 stranded specimens and one possible live sighting, this species can only be described as rare. The species is not known to have been commercially exploited or captured (Mitchell 1975). No other information is available on population status.

Habitat

The distribution of *Mesoplodon carlhubbsi* along the Japanese coast appears to coincide with the surface Transition Domain and at depth with the Subarctic Current System where deep elements of the Kuroshio and Oyashio currents mix. The North American distribution coincides with the surface Dilute and Upwelling domains and with the confluence of the Subarctic and California current systems at depth (Favorite et al. 1976; Mead et al. 1982).

The distribution is probably more directly related to the distribution of the prey species on which it feeds (mesopelagic squid and fish) than to the character of the water mass (Mead et al. 1982). However, the distribution of the prey may be directly related to the character of the intermediate and deep water masses.

General Biology

Although only a limited number of specimens have been examined, length at physical maturity appears to be at around 5 m. Presumably, growth occurs more slowly after physical maturity, until a maximum observed length of 5.3 to 5.4 m is reached (Mead et al. 1982; Mead 1984). To date, there are no estimates of longevity.

Examination of neonate specimens (from strandings) indicates that calving probably takes place in the summer and that the gestation period is about twelve months, as for other small cetaceans (Mead et al. 1982). No information is available on breeding or calving and it is not known if the species makes seasonal migrations. The largest recorded fetus measured 0.9 m and the smallest calf 2.47 m; the mean length at birth has been estimated to be 2.5 m (Mead 1984).

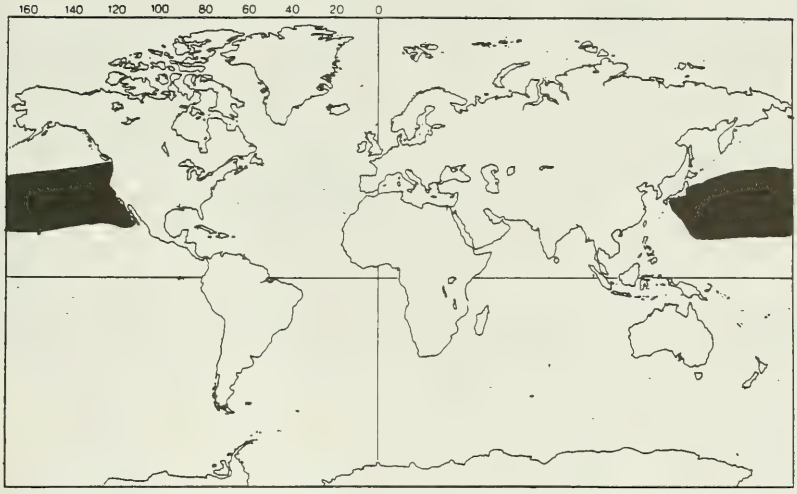

FIGURE 2. Distribution of Hubbs' Beaked Whale.

The linear scars on the bodies of adult males have been attributed to aggressive use of the teeth by other males of the same species (Heyning 1984). Heyning suggests that the structure of the teeth has evolved in relation to social interactions involving the establishment of breeding territories rather than for the acquisition and manipulation of food items. Stomach contents retrieved from stranded specimens suggest a diet of squid and fish (Mead et al. 1982).

No information is available on internal parasites or diseases. Externally, the species may be parasitized by the copepod *Penella* (Ivashin and Golubovsky 1978) and possibly balanomorph and lepadomorph barnacles (Mead et al. 1982).

Limiting Factors

None known. Rarity is the present main protection of the species, in concert with a distribution in less frequented waters and unexploited food species.

Special Significance of the Species

Hubbs' Beaked Whale has only recently been described (Moore 1963) and can easily be confused with other members of the genus, particularly Stejneger's Beaked Whale and Andrew's Beaked Whale (*Mesoplodon bowdoini*) where the ranges overlap (Watson 1981). The species is not known to have been hunted, although occasional specimens might be taken during other fishing operations. None has been reported in captivity, but study of captive individuals, if possible, would provide useful information, otherwise difficult to obtain in the wild.

The only parts and derivatives that would be likely to appear in trade would be scientific specimens. It is unlikely that such a rare species could support a fishery or would be of commercial interest.

Evaluation

The species is a member of the pelagic fauna of the Pacific waters of Canada. Although nothing is known of its habit or life history in Canadian waters, it appears to be a rare component of this ecosystem. The species is under no imminent threat in Canadian waters and COSEWIC status is probably neither warranted nor required at this time.

Acknowledgments

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Status of Sowerby's Beaked Whale, *Mesoplodon bidens*, in Canada*

JON LIEN and FRANCES BARRY

Department of Psychology and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9

Lien, Jon, and Frances Barry. 1990. Status of Sowerby's Beaked Whale, *Mesoplodon bidens*, in Canada. Canadian Field-Naturalist 104(1): 125–130.

Sowerby's Beaked Whale of North Sea Beaked Whale, *Mesoplodon bidens*, has been encountered only 11 times in the western North Atlantic through two mass strandings, seven strandings of individuals and in two sightings. There are more recorded strandings of this whale on British and European coasts but its range appears to be generally offshore throughout the North Atlantic. Because of the paucity of encounters with *Mesoplodon bidens*, little is known of its biology.

La baleine à bec de Sowerby (dauphin du Havre), *Mesoplodon bidens*, n'a été repéré que onze fois dans l'ouest de l'Atlantique Nord, lors de deux échouages en masse, sept échouages d'individus isolés et deux observations. Bien que les relevés d'échouages soient plus fréquents sur les côtes britanniques et européennes, l'aire de répartition de cette espèce semble couvrir généralement en haute mer tout l'Atlantique Nord. La biologie de *Mesoplodon bidens* est peu connue en raison du nombre extrêmement réduit d'observations.

Key Words: Sowerby's Beaked Whale, *Mesoplodon bidens*, North Sea Beaked Whale, dauphin du Havre, baleine à bec de Sowerby, Cetacea, odontocetes, ziphiids, beaked whales, *Mesoplodon*, rare and endangered species.

Mesoplodon bidens (Sowerby 1804), Sowerby's Beaked Whale, is also known as the North Sea Beaked Whale. The former name refers to the describer of the first specimen found in Scotland in 1800 (Katona et al. 1983). Little is known of its distribution and biology. Only a few papers discuss the species, usually incidentally, in general reports of stranded cetaceans.

Early reviews of the beaked whales in general (Flower 1872, 1878; True 1910) were based on limited numbers of specimens and several species were not recognized. The genus *Mesoplodon* comprises twelve different species, most of which are poorly known and generally regarded as rare (Leatherwood and Reeves 1983). Seven species are now recognized in the Northern Hemisphere (Moore 1966) and occur in both Atlantic (Ulmer 1941) and Pacific waters (Orr 1953). However, two species are found only in the Pacific, *Mesoplodon stejnegeri* and *Mesoplodon bowdoini* (Moore 1966). Occurrence of *Mesoplodon bidens* is restricted to the North Atlantic. General reviews of beaked whales of the genus *Mesoplodon* are given by Moore (1966) and Leatherwood and Reeves (1983).

Mesoplodon bidens is a medium-sized beaked whale known to reach 5 m in length (Figure 1). Adults are dark charcoal grey on the back with light spots overall. Young animals are also dark charcoal grey on the back but are lighter on the belly and unspotted (Leatherwood et al. 1976). The unnotched flukes of adults are dark above and below. The spindle shaped body has relatively long pectoral flippers which are about 1/8 body length. Family characteristics include the long narrow snout and v-shaped slashes or grooves on the throat (Figure 2). Positive field identification of most species is difficult, but may be simplified by comparisons of such characteristics as mandible size and tooth position where ranges overlap (*see* Fraser 1953 *or* Watson 1981). Each side of the lower jaw has one triangular tooth. Teeth erupt above the gum in males but not in females. Positive diagnosis of stranded specimens can be based on skull characteristics (Moore 1966).

Distribution

The range of *Mesoplodon bidens*, the most northerly species of beaked whale, is poorly known but distribution estimates based on stranding events and a few sightings have been made.

There have been 30 or so strandings of this species on the European coast (Saemundsson 1939; Fraser 1953) and occasional sightings (Øynes 1974; Christensen 1977). Saemundsson (1939) and Christensen (I. Christensen, Institute of Marine Research, Bergen-Nordnes, Norway; personal communication) indicate occasional captures by Norwegian whalers off Iceland and in the Barents Sea. Sheldrick (1979) reports 29 stranding records

*Vulnerable status approved and assigned by COSEWIC 11 April 1989.

FIGURE 1. Drawing of an adult male Sowerby's Beaked Whale, *Mesoplodon bidens* (redrawn from Watson 1981).

of *Mesoplodon bidens* on the British coastline from 1913 to 1972. Moore (1966) concluded that the relative abundance of *Mesoplodon bidens* strandings on the European side of the Atlantic, in a gross way, was related to the greater abundance of animals living in that vicinity compared to the Western Atlantic. Saemundsson (1939) suggested the species has an open sea distribution with occasional visits to coastal waters.

Recent records from eastern Canada (Sergeant and Fisher 1957; Dix et al. 1986; Lien et al. 1990) suggest that the animals frequent waters off this coast fairly regularly. Altogether, seven individual strandings, two mass strandings involving a total of nine whales, and two live sightings of *Mesoplodon bidens* have been recorded from 1906 to 1988 in the Western North Atlantic. These are listed in Table 1 and locations are shown in Figure 3. Most of these events have been recorded in the last 15 years and over half in the past four years. This does not likely indicate an influx or redistribution of the species to the western North Atlantic, but rather reflects recent increases in the efficiency of North American stranding networks (Lien et al. 1990) as well as verifiable field identification through the use of photography.

Mesoplodon bidens was first recorded in the Northwest Atlantic on U.S. shores in 1867 when an adult male was stranded on Nantucket Island, Massachusetts (Allen 1906). A stranding of a 488 cm female occurred at Nantucket, Massachusetts in September 1982. The most recent U.S. stranding was of a 457 cm male which occurred at Port St. Joe on the Gulf Coast of Florida in October 1984 (J. G. Mead, Division of Mammals, Smithsonian Institution, Washington, D.C.; personal communication).

The remaining specimens of *Mesoplodon bidens* in North America were all recorded in Newfoundland and Labrador. Two were discovered in consecutive summers (Sergeant and Fisher 1957); a 472 cm adult male was found dead in August 1952 in Trinity Bay (47°45′N, 53°52′W), and a 427 cm immature female was harpooned in Notre Dame Bay (49°40′N, 55°50′W) in September 1953. A third partial animal, probably a female, came from Labrador (54°10′N, 58°35′W) in September 1973 (J. G. Mead, personal communication). A 410 cm male was found dead in July 1984 in Conception Bay, Newfoundland (47°34′N, 53°11′W) and was assumed (from photographs) to be the same whale which had been sighted and released from fishing gear two days previously (Dix et al. 1986).

Mass strandings of *Mesoplodon bidens* have occurred for two consecutive years on the northeast coast of Newfoundland. Three whales, all males 462, 485, and 495 cm in length, died and were examined from a group of six individuals which stranded in August 1986 near Carmanville, Newfoundland (49°07′N, 54°18′W) [Lien et al. 1990]. In September 1987, reports of three whales beaching on several occasions near Norris Arm, Newfoundland (49°07′N, 55°15′W) led to the discovery and examination of a single 462 cm female (Lien et al. 1990).

Protection

Mesoplodon bidens is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). In waters under Canadian jurisdiction, *Mesoplodon bidens* is protected by the Fisheries Act. In the United States, it is classified as endangered and protected under the Marine Mammal Protection Act.

Population Size and Trends

There are no estimates of the population size of *Mesoplodon bidens* due to insufficient data. The very scantiness of data on the species probably indicates this whale is quite rare.

Following the inception of the comprehensive stranding network in Newfoundland in 1979 (Lien 1980; Lynch 1988), verified sightings or strandings of *Mesoplodon bidens* individuals or groups have averaged 0.30 per year. This compares to an average of 0.12 sightings or strandings per year during the period 1947-1973 (Sergeant and Fisher 1957; Sergeant et al. 1970; Dix et al. 1986). Prior to this early work there were no encounters recorded with ziphiids.

Stranding networks have become more efficient in many areas of North America recently (Geraci and St. Aubin 1979; Lien 1980), and because of the

FIGURE 2. Photograph of the 362 cm female stranded at Bay of Exploits, Newfoundland in September 1987 (*see* Table 1). Note the "V" shaped throat groove.

presence of the unusual rostrum, it is likely that most stranded *Mesoplodon bidens* would be reported. Although the number of strandings reported in recent years has increased, it can not be concluded that *Mesoplodon bidens* has become more common in Canadian waters in the past decade. The increased scope and efficiency of present stranding networks, where effort is difficult to quantify, may well bias conclusions about the relative abundance of the species. However, earlier suggestions that the distribution of *Mesoplodon bidens* enters in the North Sea and only occasionally wanders to western North Atlantic waters (Moore 1966) should perhaps be regarded as premature.

Habitat

There are, at present, inadequate data to identify habitat requirements of *Mesoplodon bidens*.

Sightings of ziphiids have been common along the edges of temperature fronts in water depths of approximately 200 m (Price and Fairfield 1985) which is consistent with a sighting of *Mesoplodon bidens* by Marion et al. (1987). However, *Mesoplodon bidens* sightings have also occurred in waters of depths greater than 1500 m (Øynes 1974; Christensen 1977).

If *Mesoplodon bidens* is a pelagic species that only occasionally visits coastal waters, one might expect mass strandings of the species (Sergeant 1982; Tyack 1987). In the past three decades, the ratio of mass to single Canadian strandings of *Mesoplodon bidens* is 2:1. For British shores, the mass to single stranding ratio of *Mesoplodon bidens* is 1:29 (Sheldrick 1979). Sheldrick (1979) makes the point that mass strandings are generally considered rare for all species on British coasts.

TABLE 1. Records of *Mesoplodon bidens* in North America (1867-1988).

Date	Location	Details	Source
1867	Nantucket Island, Massachusetts	male	Allen (1906)
25 Aug. 1952	Chapel Arm, Trinity Bay, Newfoundland (47°45′N, 53°52′W)	472 cm male NMC-26483	Sergeant and Fisher (1957)
23 Sept. 1953	Wild Bight, Notre Dame Bay, Newfoundland (49°40′N, 55°50′W)	472 cm female NMC-26484	Sergeant and Fisher 1957
Sept. 1973	Labrador, Notre Dame Bay, (54°10′N, 58°35′W)	part of female	J. Mead (personal communication)
10 Sept. 1973	Nantucket, Masschusetts	488 cm male MH-82-180	J. Mead (personal communication)
24 July 1984	Manuels, Conception Bay, Newfoundland (47°35′N, 53°11′W)	net entrapment	Dix et al. (1986)
26 July 1984	Port de grave, Conception Bay, Newfoundland (47°34′N, 53°11′W)	410 cm male	Dix et al. (1986)
Oct. 1984	Port St. Joe, Gulf coast of Florida	457 cm female USNM 550414	J. Mead (personal communication)
30 Aug. 1986	Carmenville, Newfoundland (49°07′N, 54°18′W)	mass stranding of 6 whales; 3 males 495 cm, 485 cm, 495 cm. (Canadian Museum of Nature)	Lien et al. (1989)
July 18 1987	Hydrographers Canyon region (40°00′N, 68°54′W)	sighting — 3 adults and 2 calves	Marion et al. (1987)
Sept. 18 1987	Norris Arm, Bay of Exploits, Newfoundland (49°07′, 55°15′W)	mass stranding of 3 whales; one 362 cm female, Ontario Science Centre	Lien et al. (1989): *See* Figures 2,3

FIGURE 3. Locations of North American sightings and strandings of *Mesoplodon bidens*, 1867-1988.

Another species, the Long-finned Pilot Whale (*Globicephala melaena*), which is an offshore pelagic species and returns to coastal Canadian waters seasonally (Mercer 1975), may be somewhat comparable. For the period 1957 to 1980, Sergeant (1982) lists 12 mass strandings of *Globicephala melaena* in eastern Canada which provide a mass to single strandings ratio of about 1:1. The high ratio of mass to single strandings in Newfoundland (Lien et al. 1990) could be interpreted as support for the hypothesis that *Mesoplodon bidens* is an offshore species which tends to mass-strand rather than to strand individually, and that waters off Newfoundland are in the centre of the species range rather than at its edge (Sergeant 1982).

Sergeant and Fisher (1957) suggest that, following the habit of the Long-finned Pilot Whale, *Mesoplodon bidens* occurs inshore when the squid *Illex illecebrosus* is abundant. However, Dix et al. (1986) note that strandings of *Mesoplodon bidens* occur in years of low squid abundance and no trace of squid has been discovered in stomachs of specimens examined. Moreover, examination of oceanographic data from the years of strandings has revealed no obvious correlations with, or differences from other years which might account for the inshore appearance of *Mesoplodon bidens* (Dix et al. 1986).

Biology

Very little is known about the life history of *Mesoplodon bidens*. The limited knowledge available has been derived from stranded specimens and the few verified field sightings.

Age of breeding is unknown. Females with overall lengths of 483 cm (Reiner 1986), and 505 cm (Jonsgård and Hoidal 1957) were mature, whereas one 462 cm female was immature (Lien et al. 1990). Males under 5 m have been considered immature (Sergeant and Fisher 1957; Dix et al. 1986; Lien et al. 1990). Mead (1984) reports a maximum recorded length of 5.5 m for males. Fetuses of 54 cm (Reiner 1986), 158, and 121 cm have been reported, and Greig (1908) found a very young calf measuring 245 cm in length with a remnant of umbilical cord (Greig 1908). Jonsgård and Hoidal (1957) conclude that calves must be from 150 to 250 cm in length, most likely between 180 to 210 cm at birth and that mating and birth occur in late winter and early spring after a gestation of about one year. They also suggest, based on what was assumed to be a mother and calf, that weaning may occur after about a year when the calf is about 300 cm in length.

There are too few observations of *Mesoplodon bidens* to infer much about its movements and behaviour.

Ziphiids are usually found singly, or in small groups and *Mesoplodon* species, in particular, have been found to have the least social cohesion of the medium-sized odontocetes (Gaskin 1982). Some observations of *Mesoplodon bidens* appear to support this view.

Groups of *Mesoplodon bidens* may be segregated by sex. The low probability of a mass stranding of three males from a group of six individuals suggests the hypothesis that all-male social groups occur (Lien et al. 1990). The possibility of sexual segregation in *Mesoplodon bidens* raises hypotheses explaining their social structure. Gaskin (1982) has related segregation by sexes to differences in food requirements of males and females or to their polygynous mating habits. However, comparisons of body measurements from a limited number of males and females indicates little sexual dimorphism in *Mesoplodon bidens* (Lien et al. 1990), except in the degree of development of the single pair of mandibular teeth (Moore 1966). The teeth erupt only in males, while females have smaller teeth which do not protrude from the gums (Sergeant and Fisher 1957). This minimal degree of sexual dimorphism suggests that polygyny may not be the mating organization (Davies and Kreb 1981; Sergeant 1982).

Limiting Factors

Unknown.

Special Significance of the Species

Mesoplodon bidens has only been reported 11 times in North American waters in the past 120 years. Sightings and strandings are rare compared

to those of other ziphiids and cetaceans generally. Study of the western North Atlantic population is very important to help understand this species and virtually any information about these whales will greatly increase our knowledge about their lives.

Evaluation

There is insufficient evidence to estimate population size and range. Since information on food and habitat requirements is also speculative, trends of populations of this species are impossible to discern or predict. Due to lack of knowledge of *Mesoplodon bidens*, and given the rarity of encounters, this species should be considered rare throughout its range until more information is available. Due to its rarity and limited Canadian distribution coincidental with major shipping lanes and areas of offshore petrochemical exploration and development, the species should be considered vulnerable in Canadian waters.

Acknowledgments

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Status of Stejneger's Beaked Whale, *Mesoplodon stejnegeri*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodlawn, Ontario K0A 3M0

Houston, J. 1990. Status of Stejneger's Beaked Whale, *Mesoplodon stejnegeri*, in Canada. Canadian Field-Naturalist 104(1): 131–134.

Stejneger's Beaked Whale, *Mesoplodon steinegeri*, is a medium-sized ziphiid of the North Pacific. The range extends from Japan to the North American coast between 50 to 60°N. The species is known only from a few stranded specimens, although unsubstantiated sightings have been recorded from Japan and Washington State. The species is of no commercial interest and is rare in Canadian waters.

La baleine à bec de Stejneger, *Mesoplodon stejnegeri*, est un Ziphiidé de taille moyenne du Pacifique nord. Son aire de répartition s'étend du Japon à l'Amérique du Nord, entre 50° et 60° de latitude nord. L'espèce ne nous est connue que par quelques spécimens échoués; il semble toutefois qu'elle ait été aparçue au Japon et dans l'État de Washington, mais ces observations n'ont pas été confirmées. L'espèce ne fait l'objet d'aucune chasse commerciale et est rare dans les eaux canadiennes.

Key Words: Stejneger's Beaked Whale, *Mesoplodon stejnegeri*, mesoplodon de stejneger, Bering Sea Beaked Whale, Cetacea, odontocetes, beaked whales, Ziphiidae, *Mesoplodon*.

Stejneger's Beaked Whale, *Mesoplodon stejnegeri* True 1885, was first named on the basis of a skull found by Leonhard Stejneger on Bering Island, Alaska in 1883. True later included a full description in an account of the family (True 1910) based on an adult male stranded near Newport, Oregon in 1904. Moore (1963, 1966, 1968) suggested that the species was the dominant subarctic beaked whale of the North Pacific and that it can easily be confused with the Splay-toothed Beaked Whale (*Mesoplodon bowdoini*), of the South Pacific.

This species is difficult to identify in the field, but any beaked whale in the North Pacific, north of 50°N latitude, lacking the white beak of Hubbs' Beaked Whale (*Mesoplodon carlhubbsi*) is apt to be Stejneger's Beaked Whale (Watson 1981; Mead et al. 1982). The only other beaked whale found as far north is Cuvier's Beaked Whale (*Ziphius cavirostris*) which has a shorter beak and exposed teeth set on the anterior end of the mandible beyond the tip of the upper jaw (Leatherwood et al. 1982).

Stejneger's Beaked Whale has the usual spindle-shaped body of the ziphiids (Figure 1) and is of medium size. Maximum length is probably 6 m with a weight of 1200 kg. The beak is long, the fulcate dorsal fin is behind the midline and there is no medium notch between the flukes (Leatherwood et al. 1982). The flippers are small and there are a pair of throat creases typical of beaked whales. There is a well-developed keel from the dorsal fin to the flukes (Watson 1981). Two mandibular teeth which dorsally constrict the upper jaw erupt in males.

As with most other ziphiids, few of these whales have been observed alive and the species is known mainly from strandings. The colour pattern is not well known but appears characteristically to include white blotches around the lips, sides of the head and neck, and a brown saddle across the blowhole (Watson 1981). The animals are grayish brown dorsally and lighter on the ventral surface. Adults are usually heavily marked with oval white scars on the flesh and underbelly and adult males demonstrate linear scars which may result from intraspecific aggression (Leatherwood et al. 1982; Heyning 1984).

Distribution

Stejneger's Beaked Whale is known almost entirely from records of strandings and from stranded specimens, which suggest the species is endemic to the subarctic and cold temperate waters of the North Pacific (Figure 2) principally between 50° and 60°N (Moore 1966).

The species has been recorded from Japan in the west and from Alaska to Monterey, California, in the east (Moore 1966; Watson 1981; Leatherwood et al. 1982). Stranding records exist from Vancouver Island (Pike and MacAskie 1969) suggesting that the waters off Canada's Pacific coast are within the normal range of the species.

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

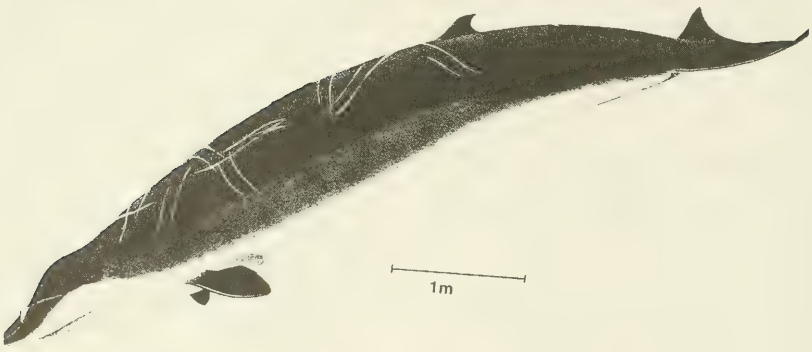

FIGURE 1. Stejneger's Beaked Whale, *Mesoplodon stejnegeri* (redrawn and adapted from Watson 1981).

Protection

International: All *Mesoplodon* species are included on Appendix II of the Convention on International Trade in Endangered Species (CITES). Such species are not considered to be rare or endangered but could become so if trade were not regulated. Listing on Appendix II requires management by range states and export permits from country of origin for export of parts, specimens, or their derivatives. Mitchell (1975) lists the species as one not generally taken or of interest to whalers. The species is listed in the Red Data Book of the International Union for the Conservation of Nature as of "Indeterminate" status (Goodwin and Holloway 1972).

National: Protected by general legislation in several countries but no specific provisions are known. In Canada, general protection is granted under the Fisheries Act and the Cetacean Protection Regulations which prohibit whaling. In the United States, general protection is provided under the Marine Mammals Protection Act of 1972 and the Endangered Species Act.

Population Sizes and Trends

The species is known only from limited stranding records which are few and far between. Only seven specimens were recovered between 1910 and 1960 from Alaska (4), to Vancouver (1), to Washington (1) and Oregon (1) [Moore 1966]; one additional individual was found in Japan during this same period. Since 1960, an additional five strandings have been reported (Watson 1981), mostly from the Aleutian Islands, but one individual was found near Monterey, California (Leatherwood et al. 1982). There are unconfirmed reports of sightings in the Sea of Japan (Nishimura and Nishiwaki 1964) and coastal Washington (Mitchell 1975).

Although Mitchell (1975) felt that numbers may not be as low as sightings and strandings might indicate, these whales are undoubtedly rare in Canadian waters and have apparently been harvested in Japan by Japanese coastal whalers on occasion (Mitchell 1975). No other information is available on population status.

Habitat

The distribution of Stejneger's Beaked Whale appears to coincide with the Subarctic current systems described by Favorite et al. (1976). The distribution may not be as directly related to oceanographic parameters as it is to the prey species. However, the distribution of its prey (squid, pelagic fish) is no doubt related to characteristics of the water mass (Favorite et al. 1976; Watson 1981).

The species seems to occupy the same subarctic niche as Sowerby's Beaked Whale (*Mesoplodon bidens*) in the North Atlantic (Moore 1966; Watson 1981) where the latter species also appears to be restricted to cooler, offshore waters where squid are plentiful (Sergeant and Fisher 1957).

General Biology

There is very little information on the natural history of the species. Stomach contents of specimens taken by Japanese coastal whalers are said to consist of squid and pelagic fish (Nishiwaki and Kamiya 1959). The species is also reported by the whalers to occur in small groups of two to three individuals. The largest reported female was 5.3 m in length as was the largest recorded male (Mead 1984). No fetuses or calves have been reported and no other morphometric data appears to be available.

Limiting Factors

Owing to the paucity of information on the species, nothing is known of factors which could be limiting the population(s). Their solitary habits,

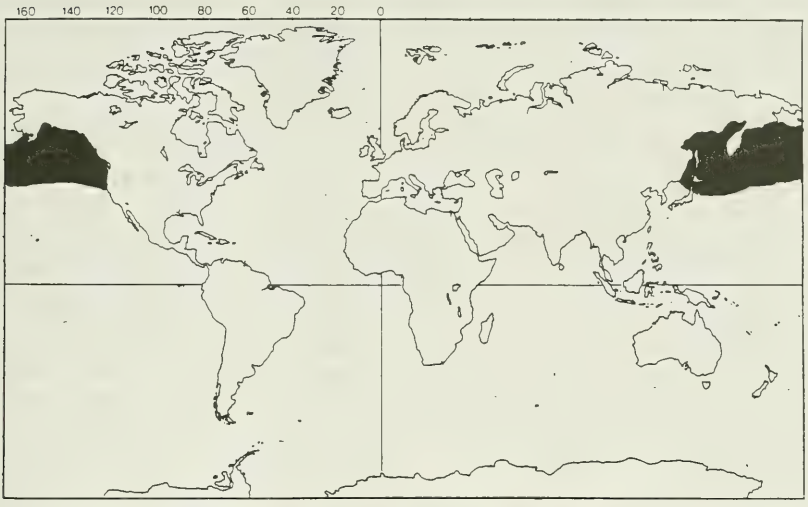

FIGURE 2. Distribution of Stejneger's Beaked Whale.

distribution and apparent rarity may serve to offer some protection from human exploitation. Apparently, animals have been taken occasionally by Japanese whalers in coastal fisheries (Nishiwaki and Kamiyu 1959). The species does not appear to have been commercially exploited and the occasional removal of a few individuals is unlikely to affect the population(s). Commercial exploitation is not likely, but would probably seriously affect existing populations.

Special Significance of the Species

The population is generally too small and individuals too scarce to be of commercial interest, although some species of *Mesoplodon* may have been fished in the 19th Century, or earlier, by American and other whalers (Mitchell 1974). The blubber and flesh of the species is thought to cause diarrhoea (Mitchell 1975; Mead et al. 1982).

It is improbable that parts or derivatives of the species would be involved in international trade. The species has not been held in captivity and such an event would only come about by chance.

Evaluation

Little information is available for assessment of population status. Although small groups have been observed chasing schools of salmon in the Sea of Japan (Nishimura and Nishiwaki 1964). Sightings in Canadian waters are few. However, the species was known to the Makah Indians of Washington who were said to have talked of seeing these whales in twos or threes one-half to one mile offshore (*see* Mitchell 1975). Based on the above observations, Mitchell (1975) felt the numbers may not be small. It is probably rare, at least in Canadian waters, but there are no imminent threats to its survival here. The species need not be considered for COSEWIC status at this time.

Acknowledgments

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Watson, L. 1981. Sea guide to whales of the world. Nelson Canada Limited, Scarborough, Ontario.

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Status of True's Beaked Whale, *Mesoplodon mirus*, in Canada*

J. HOUSTON

374 Fireside Drive, Woodland, Ontario K0A 3M0

Houston, J. 1990. Status of True's Beaked Whale, *Mesoplodon mirus*, in Canada. Canadian Field-Naturalist 104(1): 135–137.

True's Beaked Whale, *Mesoplodon mirus*, is a medium-sized cetacean of the family Ziphiidae found in the temperate North Atlantic and the southwestern Indian Ocean. Known mainly from stranded specimens, the species is probably pelagic, but occasionally seen in coastal waters. It is not known to have been commercially exploited or taken in other fisheries operations. The species is probably rare in Canadian waters.

La baleine à bec de True, *Mesoplodon mirus*, est un cétacé de taille moyenne appartenant à la famille des Ziphiidés et fréquentant les eaux tempéres de l'Atlantique nord et du sud-ouest de l'Océan Indien. Les données disponibles sur l'espèce proviennent d'individus échoués; probablement pélagique et rare, elle évite les zones côtières. On ne sait pas si elle a fait l'objet d'une exploitation commerciale ou si elle a été capturée au cours d'autres opérations de pêche. L'espèce est probablement rare dans les eaux canadiennes.

Key Words: True's Beaked Whale, Wonderful Beaked Whale, *Mesoplodon mirus*, baleine à bec de True, Cetacea, odontocetes, ziphiids, beaked whales, *Mesoplodon*, North Atlantic.

True's Beaked Whale, *Mesoplodon mirus* True 1913, is a medium-sized ziphiid, the maximum length observed being between 5 and 5.5 m with an average weight of 1300 kg (Watson 1981; Leatherwood and Reeves 1983). The body is distinctive (Figure 1) and similar to that of Cuvier's Beaked Whale (*Ziphius cavirostris*). The head is small with a bulging forehead and short neck. The two teeth which erupt in adult males are found near the tip of the mandible. The body is chunky in the midriff, tapering towards the tail. There is a slight depression behind the blowhole. The flippers are small and positioned low and forward similar to those of Cuvier's Beaked Whale. Behind the small, curved dorsal fin, is a pronounced dorsal ridge. The flukes have a small median notch unlike those of other beaked whales (*see* Watson 1981; Leatherwood and Reeves 1983).

The species is usually bluish-gray to dark gray on the back, lighter gray on the sides and gray ventrally. Lighter spots or blotches are often found on the throat and anal regions (Watson 1981; Leatherwood and Reeves 1983). Scarring, some of which is probably from the teeth of other males, is common in adult males (Heyning 1984).

As with other ziphiids, the species is rarely observed and is known mostly from strandings. Apparently rare, at least not common in Canadian waters, the status of the species in Canada is of interest to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This report was prepared for the Committee's consideration.

Distribution

The species is known only from a few strandings and, until recently, was thought to be restricted to the temperate North Atlantic (Figure 2). In 1959, a specimen was found on the South African coast (Talbot 1960) and several others have been recorded since (McCann and Talbot 1963; Ross 1969). The occurrence of *M. mirus* in the South Atlantic may represent a geographically separate stock, or that the range may be wider than previously thought (Leatherwood and Reeves 1983).

In the North Atlantic, strandings have been recorded from Florida to Nova Scotia in the west, and on the west coast of the British Isles in the east (Sergeant and Fisher 1957; Moore 1966; Brown 1975). Most strandings have been recorded along the North American coast, the centre of distribution is about 38°N (Moore 1966). Moore (1966) considered *Mesoplodon mirus* to be allopatric with Sowerby's Beaked Whale (*Mesoplodon bidens*), which occurs more frequently in European waters and further to the north.

Protection

International: The species, along with other members of the genus is listed on Appendix II of the Convention on International Trade in Endangered Species (CITES). No other international agreements refer to the species. Mitchell (1975a) considered the species to be of Indeterminate Status and it is listed as such in the Red Data Book (Goodwin and Holloway 1972).

*Reviewed and Accepted by COSEWIC 11 April 1989 — no designation required.

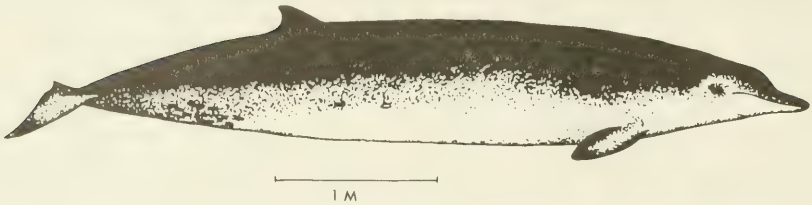

FIGURE 1. True's Beaked Whale, *Mesoplodon mirus* (redrawn and adapted from Watson 1981).

National: The species is protected by general legislation in several countries but no specific provisions are known. In Canada, general protection is provided under the Cetacean Protection Regulations promulgated under the Fisheries Act. In the United States, general protection is provided under the Marine Mammals Protection Act and the Endangered Species Act.

Population Sizes and Trends

As with other ziphiids that are known principally from stranding records, it is not possible to determine population numbers. They have not been subject to commercial exploitation and it is unknown if the numbers have changed over the last century (Mitchell 1975a, 1975b). It may be more widespread than previously thought as the South African strandings are probably indicative of a separate stock (McCann and Talbot 1963; Ross 1969; Watson 1981).

Only one stranding has been reported in Canada, on Cape Breton Island in 1938 (Moore 1966), and this is the most northerly record from the western North Atlantic. Other North American strandings are few (eight) and have occurred along the United States coast from Maine to Florida. In the eastern North Atlantic four records exist, one from the Orkney Islands and three from the west coast of Ireland (Moore 1966; Brown 1975; Watson 1981). Since this is a pelagic species, it is rarely encountered alive and no verified sightings at sea are known.

Habitat

As the species is rarely observed, there is no information on its habitat, except for the limited distributional data provided by strandings. The species' diet appears to consist of squid and deep-water fish (Mitchell 1975b; Watson 1981), thus True's Beaked Whale probably inhabits the open ocean rather than coastal areas, as do most other ziphiids.

General Biology

Very little is known about the life history of the species. Most information comes from stranded individuals. They appear to eat squid and pelagic fish (Mitchell 1975b; Watson 1981) and are likely solitary. Calves are probably born in the spring and are about 2 m long at birth (Brimley 1943; Moore 1966; Watson 1981).

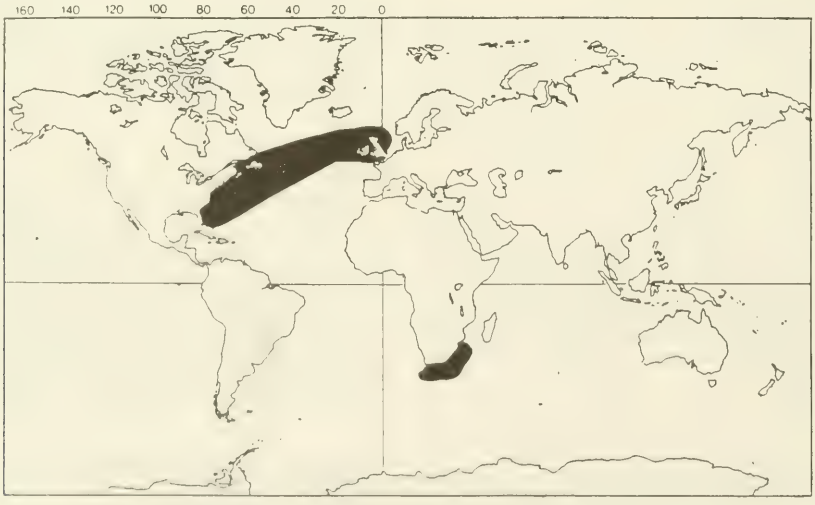

FIGURE 2. Distribution of True's Beaked Whale, *Mesoplodon mirus*.

The largest female reported was 5.1 m and the largest male 5.3 m; the shortest calf measured was 2.3 m and the largest fetus 1.1 m (Mead 1984). Aside from some meager data on ovarian and testicular weights (*see* Mead 1984), no other morphometric information appears to be available.

Limiting Factors

None known. The species is not known to have been exploited commercially or taken incidentally in other fishing operations (Mitchell 1975a, 1975b). Its rarity and solitary lifestyle probably help to maintain natural protection. As the food species appear to be pelagic, these whales probably avoid coastal areas which are more apt to be subject to pollution. The species appears to be shy of ships and dives on approach (Watson 1981).

Special Significance of the Species

True's Beaked Whale is not known to be, or to have been, subject to exploitation; no specimens have been recorded in captivity.

This beaked whale is easily confused with Cuvier's Beaked Whale (Leatherwood and Reeves 1983). Identification of all beaked whales is difficult and often requires the assistance of an expert.

Evaluation

The species may be more widely distributed than previously thought but is probably nowhere locally abundant in coastal areas. No confirmed sightings have been recorded (Watson 1981) and strandings on the Atlantic coast of Canada have been few and far between. The species is probably naturally rare in Canadian waters, but is not under any imminent threat; no COSEWIC status designation is required at this time.

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Status of the Ringed Seal, *Phoca hispida*, in Canada*

MICHAEL C. S. KINGSLEY

Department of Fisheries and Oceans, Institut Maurice-Lamontagne, 850 Route de la Mer, Mont-Joli, Quebec G5H 3Z4

Kingsley, Michael C. S. 1990. Status of the Ringed Seal, *Phoca hispida*, in Canada. Canadian Field-Naturalist 104(1): 138–145.

The Ringed Seal, *Phoca hispida*, is a small seal ubiquitous in ice-covered seas in the northern hemisphere. Although it has been hunted for its meat, blubber, and hide by the native people of the north for millennia, and is also the mainstay of the Polar Bear, its populations remain stable, varying only in response to variations in the weather. It is adaptable to human disturbance of many kinds.

Le phoque annelé, *Phoca hispida*, est un petit phoque que l'on trouve dans toutes les mers couvertes de glace de l'hémisphère nord. Bien que l'espèce ait été chassée pour sa chair, sa graisse et sa peau par les autochtones du Nord pendant des millénaires, et qu'elle constitue également la principle proie de l'ours blanc, sa population demeure stable, ne variant qu'en fonction des conditions atmosphériques. Ce phoque s'adapte très bien aux perturbations anthropiques de toutes sortes.

Key Words: Ringed Seal, *Phoca hispida*, Phocidae, seals, phoque annélé, status, Canada.

Phoca hispida Schreber 1775, the Ringed Seal of the Arctic, is the smallest seal, less than half the weight of other phocids (Stirling 1977). It is dark gray, with lighter-gray rings on the back and flanks and a paler gray ventral surface (Figure 1). Mature males develop a black facial mask in the spring. Adult females in the western Canadian Arctic average 122 cm long, males 136 cm (Smith 1987). Alaskan seals are smaller (Frost and Lowry 1981).

The single pup is born about 69 cm long, weighing about 3.5 kg (Smith 1987: 37), and clad in a long, white lanugo. The first-year coat which replaces the lanugo 20 to 30 days after birth is rather longer and thicker than the typical adult coat, and less strongly marked. This coat was esteemed in the fur trade as the "silver jar" (McLaren 1958a) and was for decades a major economic resource for Arctic maritime people (Smith and Taylor 1977).

Distribution

The Ringed Seal is ubiquitous in ice-covered seas of the northern hemisphere (King 1983); of the Arctic seals, it is uniquely adapted to living and breeding in fast ice, in which it maintains breathing holes throughout the winter (Stirling 1974, 1977).

Apart from certain physically separated groups, the Ringed Seals of the circumpolar Arctic form a continuum (*Phoca hispida hispida*). Marine populations are found in the Sea of Okhotsk (*Phoca hispida ochotensis*) and the northern parts of the Baltic Sea (*Phoca hispida botanica*) and land-locked sub-species are found in Lake Saimaa in Finland (*Phoca hispida saimensis*), and Lake Ladoga (*Phoca hispida ladogensis*) in the USSR (Frost and Lowry 1981). Closely related species are found in the Caspian Sea (*Phoca caspica*) and Lake Baikal (*Phoca sibirica*) (Frost and Lowry 1981).

The Canadian range for the Ringed Seal is depicted in Figure 1. Studies on population ecology associated with intense native harvests were carried out in south-west Baffin island and Foxe Basin in the 1950s (McLaren 1958a), in south-east Baffin Island in the late 1960s (Smith 1973b), and in the western Arctic in the 1970s (Smith 1987). Site-specific studies, components of assessments of the expected environmental impacts of proposed mines, shipping, or pipelines, have been made in the Northwest Passage (Finley 1976; Finley and Johnson 1977; Smith et al. 1978; Smith and Hammill 1980a; Kingsley et al. 1985) and in the Beaufort Sea, Amundsen Gulf and Coronation Gulf (Stirling et al. 1977, 1982; Alliston and McLaren 1981; Kingsley 1984, 1986). Less is known about density and distribution in the permanent polar pack of the Arctic basin.

Protection

International Protection Measures: There are no international agreements or conventions intended to protect Ringed Seals. The International Agreement on the Conservation of Polar Bears and their Habitat protects the ecosystems of

*Reviewed and accepted by COSEWIC 11 April 1989 — no designation required.

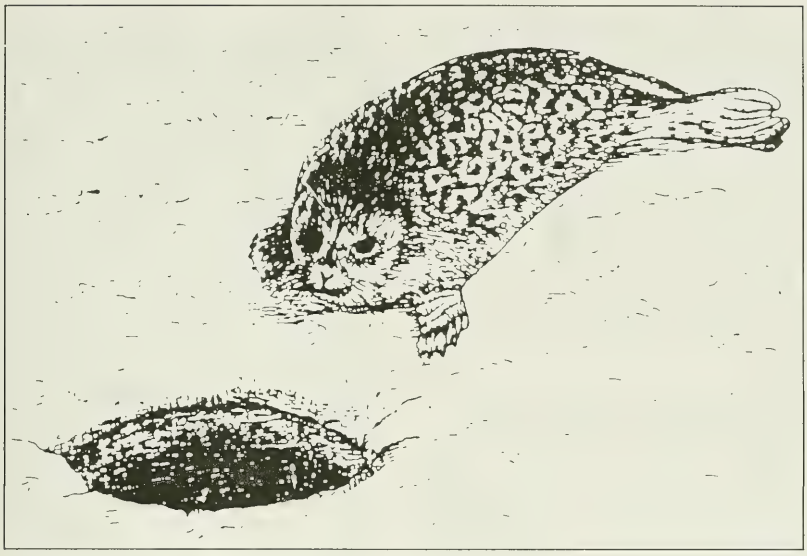

FIGURE 1. The Ringed Seal, *Phoca hispida* (drawn by J. Venables; courtesy Alaska Department of Fish and Game).

FIGURE 2. The range of the Ringed Seal in Canada.

which Polar Bears (*Ursus maritimus*) are a part with special attention, *inter alia*, to feeding sites (Stirling 1985). This implies a measure of protection for Ringed Seals and their habitat.

National Protection Measures: Seals in the Canadian Arctic are protected under the Seal Protection Regulations made under the Fisheries Act. These permit any resident to take seals for food for himself, his family or his dogs, or to sell or trade seal meat to a resident or a traveller for the same purpose (Canada Department of Fisheries and Oceans CRC 1978). There are no restrictions on the sale or barter of seal skins produced by this harvest. There is a provision for sport sealing licences, which allow the holder to take two seals. Less than 100 such licences are sold annually.

Vulnerable species are gregarious, migratory or valuable. The Ringed Seal in the Canadian Arctic

is protected *de facto* by its wide, uniform distribution, its sedentary habits, and its low value. Seal skins were worth $25 to $30 in the mid 1970s (Smith 1979), but owing to the protest against the northwest Atlantic Harp Seal (*Pagophilus groenlandicus*) harvest, they are now of little value in the fur trade (Hertz and Kapel 1986).

In Alaska, all marine mammals come under the United States Marine Mammal Protection Act of 1972, which restricts harvest to coastal natives for subsistence or the production of authentic handicrafts, and restrains regulation of native harvest of marine mammals unless a population is found to be depleted.

Population Densities, Sizes and Trends

The Ringed Seals in the circumpolar Arctic form a genetic continuum; separate populations have not been defined for any areas of the Canadian Arctic, nor have principles been established on which such a definition might be attempted. Little is known about individual movements but returns from tagged seals have shown that sub-adults may travel long distances (Smith 1967).

Numbers can be estimated by shipborne line transect survey, and corrected for submerged animals (McLaren 1961; Eberhardt 1978; Eberhardt et al. 1979). Density indices may be based on satellite or high altitude aerial counts of the drained areas around seal holes (Finley 1979; Digby 1984) or on the frequency of vocalizations (Stirling 1973; Stirling et al. 1983; Calvert and Stirling 1985). Searching the ice in winter or spring with dogs which can smell out lairs and breathing holes, has been used (Smith and Stirling 1978; Smith and Hammill 1980b), but is slow and expensive. Under-snow lairs may be detected by airborne infra-red sensing (MGSK, *unpublished*). Aerial surveys flown at the summer peak of open-air haul-out can give rapid and cheap information on the relative densities of seals over wide areas. This has been the commonest recent method and many hours of such surveys have been flown (Table 1). There are problems in interpreting such density estimates, because at that time of year, seals are probably starting to move from their wintering grounds. In particular, sub-adults which wintered outside the fast-ice breeding areas invade the fast ice to find haul-out sites, and high local densities can occur behind ice edges. The fraction of seals hauled out is not accurately known. A correction factor of 2 was applied to survey data by Smith (1973a, 1975); peak haul-out has been estimated at 70 to 80% (Finley 1979; Smith and Hammill 1981). In general, high latitudes and multi-year ice have lower densities (Smith et al. 1979; Kingsley et al. 1985).

Seal densities have been measured by studies local in scope and short in duration. There is little information on trends. Repeated surveys in the Beaufort Sea from 1974 through 1979 gave highly variable estimates of total numbers (Stirling et al.

TABLE 1. Estimates of numbers and densities of Ringed Seals in the Canadian Arctic

Area	Period	Population Estimate (visible seals)	Density Range (/km²)	Reference
Beaufort Sea	1974-1979	40 000	0.1 - 0.7	Stirling et al. 1982
Amundsen Gulf	1972		0.9 - 1.1	Smith 1973a
Northern Amundsen Gulf	1981-1985	52 000	1.6 - 3.1	Kingsley 1986 and unpublished
Prince Albert Sound	1972		2.12	Smith 1973a
Minto Inlet	1972		0.18	Smith 1973aa
Prince Albert Sound	1981-1985	18 000	2.0 - 3.5	Kingsley 1986 and unpublished
Prince Albert Sound	1988	49 000	2.0 - 3.5	Kingsley and Byers, *in press*
Central High Arctic (Polar Gas Region 1)	1975		0.58 - 1.54	Finley 1976
High Arctic (173°30′-78°10′	1980-1981	90 000	0.06 - 1.2	Kingsley et al. 1985
Hudson Bay	1974	203 000		Smith 1975; Davis et al. 1980
James Bay	1974	28 000		Smith 1975; Davis et al. 1980
Baffin Bay pack ice	1978-1979	420 000	1.39	Finley et al. 1983
East Baffin Island — fast ice	1978-1979	67 000	0.86 - 2.3	Finley et al. 1983
Eastern Arctic (north, east and South Baffin Island, Foxe Basin, Hudson Bay and Strait, and Ungava Bay)		947 000		McLaren 1958b
Home Bay (East Baffin Island)	1969	33 000		Smith 1973b
Hoare Bay (southeast Baffin Island)	1969	17 000		Smith 1973b
Cumberland Sound	1969	27 500		Smith 1973b

1982), but the interpretation of these results is complicated by year-to-year variation in the ice cover when the surveys were flown. Surveys off the Tuktoyaktuk Peninsula from 1981 through 1984 gave rather constant estimates of total numbers (Kingsley 1986), and repeated surveys in Amundsen Gulf (Kingsley 1986) and a once-repeated extended survey in the high Arctic (Kingsley et al. 1985) also gave fairly stable total estimates.

Fluctuation in the price paid for seal skins, the number of dog teams, the availability of wage employment, and the abundance of other meat such as caribou have caused the intensity of seal hunting to change over the last 20 years, and resource extraction activity has increased at the same time. There is yet no indication that Ringed Seal densities have altered in response to these changes. The numbers of Ringed Seals appear to be stable, with some fluctuation in response to episodes of unfavourable weather.

Habitat

The preferred habitat of the Ringed Seal is in areas which freeze every winter to stable fast ice, but which have a reliable open-water season. In extended aerial surveys of the Canadian high Arctic, densities were found to be much lower in areas in which there was little summer break-up (Smith et al. 1979; Kingsley et al. 1985). Information on density and distribution in the Arctic basin is not available. Water 50 to 150 m deep appears to be preferred. Surveys in the Canadian Beaufort Sea showed Ringed Seals to be less abundant in shallow water off the Tuktoyaktuk Peninsula (Stirling et al. 1982), and, in the high Arctic, less abundant in water deeper than 175 m. In the coastal waters of southwest Baffin Island, Ringed Seals were more numerous along complex highly-indented coastlines than simple ones (McLaren 1958a).

The preferred breeding habitat is reliable fast ice which will stay in place until pups are weaned. Breeding adults occupy this habitat and apparently maintain territories in it, aggressively excluding subadults (Stirling 1973; Smith and Hammill 1981; Smith 1987). Ringed Seals in Baffin Bay are inferred (Finley et al. 1983) to breed in the pack ice. Subadults winter in shear zones and areas of unconsolidated ice not suitable for breeding, sometimes in high densities and poor condition (M. Hammill, Department of Fisheries and Oceans, Lamontagne Institute, Mont-Joli, Quebec; unpublished data), and they are subject to intense predation by bears (Stirling and Archibald 1977).

General Biology

The female Ringed Seal matures reproductively at about 6 yrs, and age-specific pregnancy rates reach 0.88 to 0.90 by the 10+ yr age class (Smith 1987). Maturity may occur as early as 4+ yrs, but 6+ looks from the demographic tables like a normal age. A female may bear one pup a year. There is no data on intra-uterine mortality. In late winter, females dig enlarged lairs under snowdrifts in which they bear their pups in early to mid-April (Smith and Stirling 1975). One can infer from descriptions of behaviour (*e.g.* Smith and Stirling 1975) that they feed during the 30-day lactation.

Episodes of reproductive failure, lasting more than one year, have occurred in the western Canadian Arctic. Ovulation rates dropped temporarily to less than half normal values in the western Arctic in 1973 to 1975 (Stirling et al. 1977; Smith and Stirling 1978; Smith 1987), presumably owing to a winter and following summer of heavy ice cover. At Sachs Harbour in 1987, ovulation rates were low and the 1984 to 1987 cohorts were infrequent in collections in 1987 and 1988 (Kingsley and Byers 1988, 1989).

The males are larger than the females and, in the breeding season, give off a strong acrid odour associated with the apocrine glands in the face (Smith 1987). Ringed Seals are thought to be polygynous; males probably establish and hold underwater territories that include the birth- and haul-out lairs of several females. Females ovulate and mate at about the time of weaning in mid- to late May, but the blastocyst does not implant until August or September; active pregnancy lasts on average for about 240 days (Smith 1987).

Movements: The Ringed Seal in Canada is pelagic in open water in summer, not hauling out on land except under imminent threat from aquatic predators (T. Smith, Department of Fisheries and Oceans, Arctic Biological Station, Ste-Anne-de-Bellevue, Quebec; personal communication). As ice forms, consolidates, and thickens, seals move into it to establish home ranges (Burns et al. 1980), maintaining breathing holes by scratching away the ice with their foreclaws. Splashes and exhalations form an icy dome over the top (Smith and Stirling 1975). In mild weather in early winter, seals may enlarge holes and haul out in the open. As snow cover develops, seals maintain holes, or make fresh ones, under snowdrifts, and dig haul-out lairs within the drifts. Temperatures within these lairs are between -2° and -8°C (M. Kingsley, *unpublished data*) at ambient temperatures of -35°C.

From mid-May on, seals haul out in the open air at holes or on the edges of narrow cracks to bask in the sun and moult; they feed little at this time, and lose weight (McLaren 1958a; Smith 1987). Haul-outs may last up to 40 h, but are usually shorter (Smith and Hammill 1980b). The longest haul-out recorded for an individual was 40.5 h [Smith and Hammill 1981: Table 5 (note that this was the tail of a skewed distribution)]. More seals haul out in

the middle of the day (Finley 1979; Smith and Hammill 1981) with a daily peak of haul-out at 1500 h at the start of the haul-out season, becoming less clearly defined later. As the ice breaks up, seals move to haul out at holes and cracks behind retreating ice edges, and very high local aggregations result: 15 seals may be seen ringing a single hole, or 200 along a kilometre of crack. Ringed Seals will only haul out at holes or narrow cracks in fast ice or in the middle of very large floes, not on the edge of wide leads or ice floes (M. C. S. K., *unpublished*). As the ice rots and breaks up, they become aquatic and start to feed intensively to regain condition lost in the moulting fast. Ringed Seals may aggregate in summer into large groups, apparently feeding on local concentrations of food (Smith 1987).

Maturing subadults move into the breeding areas and establish home ranges, probably staying in the same area throughout their reproductive lives. Longevity of 43 yrs has been observed, but few seals over 20 yrs occur in the wild (Smith 1987).

Behaviour and Adaptability: The Ringed Seal is asocial. Apart from loose feeding aggregations in summer open water, adult Ringed Seals are solitary, and live in a state of mild mutual repulsion. Groups of seals hauled out at holes are rarely large, even in areas of high density (Finley 1976; Kingsley 1989), and aggression between seals at haul-out sites is frequent (Smith and Hammill 1985).

Vocalization in Ringed Seals is not well developed or frequent. Wide-band underwater barks and yelps may be heard about breeding time, associated probably with a short-range antagonism, but they are infrequent and quiet. At other times of the year, Ringed Seals seem to be less vocal (Stirlng 1973; Stirling et al. 1983).

Ringed Seals, especially experienced adults, are alarmed by disturbances that are new, close or loud. They leave lairs they are hauled out in at the sound of footsteps on the ice or at the sound of a landing helicopter (Burns and Kelly 1982). They dive when aircraft, especially helicopters, fly low over them. Densities were lower close to Eskimo villages in Alaska than further away, probably because of hunting and snowmobile traffic (Burns et al. 1980), and seals were displaced from the immediate area of seismic activity (Burns and Kelly 1982). However, they easily get used to a wide spectrum of human activities and disturbances which are repeated and not intrusive. Investigations in the Canadian and Alaskan Beaufort Sea failed to show any lower seal densities in areas affected by through-the-ice seismography or other industrial activity (Alliston 1980; Burns and Kelly 1982; Kingsley 1984; Frost et al. 1985; Kingsley 1986) and the abundance and availability of seals in winter leads, due to drilling rigs in the Canadian Beaufort Sea, attract Polar Bears (Stirling 1988). Hauled-out seals will become accustomed to repeated passage of snowmobiles and the density of Ringed Seals off the end of the runway at Resolute, Northwest Territories, was not lower than elsewhere in spite of heavy aircraft traffic and frequent snowmobile passages (Calvert and Stirling 1985).

Food Habits and Feeding: The Ringed Seal is an opportunistic feeder on pelagic organisms. Sessile benthos is not prominent in the diet, but demersal invertebrates are taken (Frost and Lowry 1984). In the ice season, the Arctic Cod (*Boreogadus saida*) is the mainstay in most areas, but other fishes such as Saffron Cod (*Eleginus gracilis*) are important at some times or in some areas (Lowry et al. 1980). In the open-water season, invertebrates are equally important. Invertebrate diet composition varies from area to area; mysids (*Mysis oculata*), and amphipods, especially *Parathemisto libellula*, are generally important, but may be displaced by other locally more abundant species (Lowry et al. 1980; Smith 1987).

Limiting Factors

This seal is limited by its dependence on ice. In southerly waters it is exposed to competition from other seals, predation by Killer Whales (*Orcinus orca*) in open water or Walrus in unconsolidated ice, and breeding failure due to unstable ice or to snow cover inadequate to protect the newborn pup from the weather or predators. The species has been generally studied in areas of abundance, and its interactions with other species at the edges of its range are not well known.

Limits on Density: Territoriality among the adult seals limits the density in the fast ice breeding habitat (Stirling et al. 1981). It is not known what determines the size of the home range that a breeding female will try to maintain, nor whether seals behave in the same way when breeding on pack-ice; other pack-ice seals are seldom territorial (Stirling 1983). The ultimate limiting factor is thought to be food (McLaren 1958a). Within the Arctic ice range of the Ringed Seal, density and population structure respond to local variations in ice chronology (Stirling et al. 1981). Polynya localities where Walrus (*Odobenus rosmarus*) live all year are unsuitable for Ringed Seal because Walrus probably prey on any Ringed Seals they can catch and drive them out of the area (Fay 1960; Lowry and Fay 1984).

Mortality Factors: Four causes of death dominate the population dynamics of the Ringed Seal. These are hunting by humans, hunting by Polar Bears, predation on pups by Arctic Foxes

(*Alopex lagopus*), and intra-specific intolerance (Smith 1987). Predation by gulls and Ravens (*Corvus corax*) on newborn pups exposed by lack of a covering snowdrift has been recorded (Kumlien 1879: *cited in* McLaren 1958a; Lydersen and Smith 1989) and may impose a limit on distribution, but is negligible in most of the species's range. Walrus are said to prey on Ringed Seals, which shun areas where they regularly occur; this probably has only a minor population effect, but may limit distribution (Fay 1960; Lowry and Fay 1984).

The Ringed Seal was the mainstay of the recent marine Eskimo culture. It fed man and dog, and lit and heated the snowhouse and cooked the food. Its hide covered kayaks, and made spring boots, mittens, and parkas. More recently, seal pelts, especially the "silver jar" from the newly-moulted pup, were of value in the commercial fur trade. The price of seal skins, the number of dog teams, the availability of wage employment, and the abundance of other meat such as caribou have all varied in recent decades, and affected the intensity of seal hunting. The annual kill has never been exactly known; a partial record showed it to be of the order 10^5 seals/yr (Smith and Taylor 1977; Smith 1987); this is probably an underestimate even of the fur harvest and would not include those seals used only for food. Increasing preservationist influence has destroyed the market in sealskins (Smith 1987), and the native harvest is now much reduced (Stewart et al. 1986). Young seals of the year are taken for food, and their skins are still used for making spring mittens and boots and for handicrafts. A larger harvest is taken for dog food; Polar Bear sport hunt regulations require that dog teams be used, so the number of dogs has increased in recent years, and they are fed largely on seal. The usual method of hunting seals is to shoot them when they are hauled out on the ice in the early summer or from small boats in the open water. Because skins are no longer traded and because seal hunting is often regarded as a casual pastime, the total harvest of seals is difficult to estimate accurately, and there are no reliable statistics. Heavy hunting close to communities may locally reduce density (Burns et al. 1982), but density varies in short range even in unhunted areas.

The Polar Bear is an obligate carnivore. Its diet is composed of marine mammals, mostly Ringed Seals. It hunts in winter most successfully in ice-edge and shear-zone areas which tend to be densely inhabited by naive sub-adult seals, but is less successful in catching breeding adults in the fast ice. Bears were seen to catch one seal about every five days (Stirling 1974). A 200 kg bear (Kingsley 1979) has an estimated BMR of 3.7 Mcal/d; a 25 kg seal with a caloric density of 5 Mcal/kg (Stirling and McEwan 1975) yields 125 Mcal, *i.e.,* about 34 days' maintenance. Allowing for wastage, assimilation, and the difference between average and basal metabolism by a factor of 4 gives an annual average requirement of 1 seal/8.5 days. If there are about 15 000 to 20 000 Polar Bears in the Canadian Arctic (I. Stirling, Canadian Wildlife Service, Edmonton, Alberta; personal communication), each needing 40 seals/yr, their take should be of the order of 0.7×10^6 seals/yr; *i.e.*, an order of magnitude larger than the human harvest.

The Arctic Fox is frequent on the sea ice in winter. It kills newborn pups, digging into the under-snow lairs to get them. It has been estimated that locally as much as 40% of the annual production of pups may be lost to fox predation (Smith 1976), but there is no estimate of the average rate of this mortality.

The fourth cause of natural mortality is intra-specific aggression. Sub-adult seals in fast-ice areas are liable to be persecuted by adults, which bite them on the hind flippers and in the axillae, to a point where they are too frightened to go in the water. They stay on the ice or in snow lairs, where they freeze, starve or get killed by bears (Stirling and McEwan 1975; Smith and Hammill 1981; Smith 1987).

Total mortalities for hunted populations in the eastern Canadian Arctic were estimated from analysis of a catch curve at 23% for pups, 12 to 13% for sub-adults, and 10 to 11% for adults, of which natural mortalities were 13%, 5 to 9%, and 3% (Smith 1973b). In the eastern Arctic, rates were 16% for pups and 14% for other ages (Smith 1987).

Special Significance of the Species

The Ringed Seal is still important as food for man and dog in the Arctic, now less so as a source of fuel and clothing. This species is unique in its special association with the Polar Bear. Without the Ringed Seal, the Polar Bear could not survive in its present numbers. Canada is under international obligation to protect Polar Bear populations and their habitat. The Ringed Seal is also an important food source for Arctic Foxes in some areas and at some times of year. Polar Bear and fox offer the Inuit opportunities, through trapping and hunting, to use their traditional skills and aptitudes to earn cash.

Evaluation

There is now no reason to place the Ringed Seal in any category under COSEWIC.

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Book Reviews

ZOOLOGY

The Collins Guide to the Birds of Britain and Europe with North Africa and the Middle East

By Hermann Heinzel, Richard Fitter, and John Parslow. 1988. (Reissue of 1984 edition). Stephen Greene Press, Lexington, Massachusetts. 320 pp., illus. U.S. $15.95.

This is another reprint of a popular field guide by a different publisher. The copy that I have on hand is slightly different from the 1972 first edition published by Collins which sold for £1.50 at that time. The format is the same but the stock is thinner which makes the soft cover edition some 3 mm thinner. The font used is similar but appears to be finer in the new reprint and matches that of the revised edition (1984). In fact, the whole book is almost identical to that edition. The main difference is in the reproduction of the colour plates which are in general somewhat duller when compared to those of the first edition but the difference is not as marked when the 1984 edition is used as a reference.

This guide is the most comprehensive for the area it is intended for, covering most of the western Palearctic Region. All the species are depicted on the colour plates, sometimes in several plumages, and a range map is provided for nearly all the species, along with a concise text which I always found accurate and very useful. In addition, the range of the species known to breed in Britain is also depicted on individual maps collected in an appendix. This field guide will be more useful than most and appreciated by those who plan to observe birds in Europe, the USSR, the Ural Mountains, as well as Iceland and Siptzbergen, the Middle East, the Canaries, the Azores, and North Africa. It is the most comprehensive and reliable guide available for those regions at a very accessible price. I highly recommend it to anyone planning the travel to Europe and surrounding regions and watch birds, whether one may be an avid birder or a casual observer.

HENRI OUELLET

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

The Collins Guide to the Birds of South-East Asia

By Ben King, Martin Woodcock, and E. C. Dickinson. 1988. (Reissue of 1975 edition). Stephen Greene Press, Lexington, Massachusetts. 480 pp., illus. U.S. $19.95.

This comprehensive guide which covers "all the 1198 species that are known to have occurred prior to 31 May 1971 in Burma, Malaya, Thailand, Indochina (Laos, Cambodia and Vietnam), and Hong Kong" is a reprint of the original Collins edition first published in Great Britain in 1975. The present reprint has a different publisher, but the text is similar to that of the earlier version and no new titles have been added to the bibliography. The quality of the printing remains very good and the reproduction of the colour plates is excellent.

Although this book provides information that is now outdated in a few instances, it remains the best available guide for this ornithologically very diversified part of the world. It is unfortunate that the publisher did not take this opportunity to update the reprint of this important work. Its price is an excellent value and I strongly recommend it to anyone interested in the fascinating birds of southeast Asia.

HENRI OUELLET

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Birds of the Middle East and North Africa: A Companion Guide

By P. A. D. Hollom, R. F. Porter, S. Christensen, and Ian Willis. 1988. Buteo Books, Vermillion, South Dakota. 280 pp., illus. + plates. U.S. $32.50.

This field guide covers an immense sector of the Palearctic region "in North Africa, all the countries lying between the Mediterranean and the Sahara, and, in South-west Asia, Turkey and Iran, and all countries southwards." It is defined as a "companion guide" because it is meant to complement and provide more information than is given in European field guides mainly for the species not known to occur regularly in Europe. It differs

from those guides in that the information is the most recent available, that the maps are sufficiently large and clear to define quite precisely the range of the species in the area described above, and that it furnishes the user with colour illustrations for 350 species seldom illustrated in other reference material and over 100 line drawings to illustrate points mentioned in the text.

Each species entry comprises an extensive section entitled "Identification" but for those species not treated at length in other companion guides this section is quite brief, and includes a useful section on voice. The section on "Status" varies greatly in length but is usually placed near the range map of the species treated. Finally, the short section on habitat may contain brief information about nesting. Although the maps are clear and the range of the species can be "seen" at a glance because it is boldly indicated in bright red, the user should read carefully the introduction to interpret them correctly. The text is concise and accurate at least for the twenty or so species that I have checked against other descriptions or specimens. The authors often call attention to recognizable subspecies of European birds which can be of special interest to those familiar with birds in Europe but not familiar with the taxa covered in the guide.

The line drawings are particularly pleasant and well done; their location in the text should prove to be particularly useful to the user in the field. The 40 colour plates by Ian Willis are very attractive if not always perfectly accurate. They should be particularly valuable to those not well acquainted with the birds of that region. However, I am left wondering on how many species one could identify correctly using the colour plates under the taxing conditions that one is likely to encounter in this part of the world!

To sum up, I have no great hesitation in recommending this guide to whoever plans to observe birds in such a fascinating region. The price is right and the book is the best available to this date for the region, although one will need to take along one of the companion guides, particularly if one is from North America and does not know European birds too well.

HENRI OUELLET

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

An Annotated Bibliography of the Pike, *Esox lucius* (Osteichthyes: Salmoniformes)

By E. J. Crossman and J. M. Casselman. 1987. Life Sciences Miscellaneous Publication. Royal Ontario Museum, Toronto, Canada. xix + 386 pp. $18.

This publication provides a functional list of references dealing with the biology of a well-known fish species; the northern pike or pike (*Esox lucius*). Compiled by two renowned esocid specialists, this contribution, which lists over 3000 references, will be a very useful bibliographic source for many years to come.

Published bibliographies are time-saving tools. With the number of scientific and popular journals presently found on the shelves of libraries, one can easily feel overwhelmed by the task of doing a literature search on a specific subject, specially one that has been treated as extensively as *Esox lucius*.).

The book begins with an essay entitled "The Protohistory of Pike in Western Culture" by Richard C. Hoffman. We learn that the first direct literary reference to the pike (in fact to *lucius*) was made by a Roman poet, Decimus Magnus Ausonius (310-393 A.D.), in a Latin poem entitled *Mosella*. Hoffman reports various other historical facts related to the pike and tries to interpret them within the framework of the intellectual preoccupations of each period. The essay is interesting and instructive.

In my opinion, a good bibliography must show the two following qualities: (i) it must be exhaustive, and (ii) it must have a good subject index in order to provide its user with a quick and easy access to specific groups of references.

The bibliographic portion of the text is voluminous (325 pages). References are organized in standard alphabetic (authors) and chronological orders. Since *Esox lucius* has a circumpolar distribution in the temperate waters of the northern hemisphere, the authors were careful not to restrict themselves to North American references and have made a honest effort to include contributions from the United Kingdom, Europe, and Asia. Titles are indicated in their original language with several followed by an English translation. My first language being French, I found the absence of diacritical marks a bit disturbing. Anglers and naturalists will be happy to know that several articles from popular magazines are listed.

The access to this huge reference list is facilitated by a good subject index which occupies 51 pages. There are 37 categories dealing with various biological themes. These categories are explained in the Introduction to the bibliography section. They include subjects such as: "Accounts by

Geographical and Political Areas", "Anatomy, Morphology and Histology", "Angling and Record Catches", Culture and Artificial Propagation", "Life History and Habitats", "Management", "Marking and Tagging", "Physiology and Biochemistry", "Popular Accounts", "Reproduction" and "Toxicology and Contaminants". In addition to this index, descriptive or informative annotations were added to some references in the bibliography itself. These are useful to the reader since they give a general idea of the publication's content without having to hunt for it.

It is by frequent usage that the qualities and shortcomings of a bibliography become apparent. However, I believe that this publication satisfies all the basic requirements that will make it a useful tool for anybody interested in a fish species allegorically referred to as the "aquatic wolf" or the "tyrant of the waters".

FRANÇOIS CHAPLEAU

Department of Biology, University of Ottawa, Ottawa, Ontario K1N 6N5

Sharks

Edited by John D. Stevens with illustrations by Tony Pyrzakowski. 1987. Facts on File, New York. 240 pp., illus. U.S. $29.95; $40.95 in Canada.

Sharks have a fearsome reputation among the uncritical consumers of movies and sensational newspaper reports, but bee stings and dog bites are more fatal to humans than the maligned shark. Once past this undeserved reputation, sharks are a fascinating group of fishes with a wide variety of body forms, behaviours, physiologies, adaptations, and other features well worthy of yet another book about them.

This particular book has 17 contributors, in addition to the consulting editor and illustrator, ranging from professional ichthyologists to painters, divers, photographers, and science writers with several of these skills being found in a single individual. Some of the information in the text is not merely compiled from other books but is based on experience and original research of the contributors. The aim of the book is to provide the interested general reader with a balanced and comprehensive survey of sharks and their biology.

The book contains 64 pages on shark attacks in different parts of the world. Certainly, sharks will attack people but it has been estimated that well over 50% of attacks are unrelated to feeding, more than 75% of victims were struck only once or twice, and less than 30% of attacks were fatal. People are just not part of the normal diet of sharks, yet the fear of being eaten is morbidly fascinating. Other sections deal with evolution, kinds of sharks, distribution, biology, senses, ecology, behaviour, legends, uses, encountering sharks and repelling them, and even how to photograph them. The book ends with a checklist, a selected and rather short bibliography of 77 items including books and certain scientific articles, brief biographies of the contributors, and an index.

This is a large format book replete with superb colour photographs and paintings on every page. Text is therefore limited but a very good read. Errors are few and one I noticed was the record of 27 people who suffered a "mass attack" in 1949 with 14 deaths near Ahwaz, Iran. These attacks actually occurred spread over the period 1941-1949, numbered 24 (and possibly 36 or more) with 16 (or more) deaths. The original data is somewhat vague but it is clear that shark attacks in fresh waters draining to the head of the Persian Gulf are common and ongoing based on recent studies by the reviewer for the period 1938-1985.

Layout is generally excellent. Some topics are separated into boxes, further chopping up the text, but I did not find this annoying, perhaps because I dipped into this book at intervals rather than settling to a solid read. The index works well.

This book is warmly recommended as the best available on a well-worn topic.

BRIAN W. COAD

Ichthyology Section, Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

Suivi de la pêche sportive dans les eaux de la région de Montréal

Par P. Fournier, M. Beaudoin, and L. Cloutier. 1987. Gouvernement du Québec, Ministère du Loisir, de la Chasse et de la Pêche, Direction générale de Montréal, Service de l'aménagement et de l'exploitation de la faune, Rapport technique no. 06-42. ix + 76 pp., illus. Free.

Sport fishing is one of the most popular outdoor activities in Canada. Being an ichthyologist but also an unconditional adept of sport fishing, I was looking forward to reading this short report. It contains a survey of the fishing activities in the

waters surrounding the heavily populated Montreal region. The study was done from April to mid-October 1985 and had as objectives the determination of the diversity of fish species caught, the size and weight of these fishes, and the most exploited areas in the catchment basins around Montreal. Particular attention was given to lakes St. Louis, St. François, des Deux Montagnes, and the St. Lawrence River between the Lachine Rapids and the Boucherville Islands. The collaboration of local outfitters and sport fishing clubs was instrumental in the success of the survey.

In all, 7568 individuals with at least one catch in their fishing basket were interviewed. They captured a total of 41 273 fishes belonging to 27 species and representing a total weight of 16 450 kg. Three species accounted for 86% of all fish captured: the Yellow Perch (65%), the Northern Pike (14%) and the Walleye (7%). In terms of weight, the Northern Pike was the most important contributor with 38%, followed by the Yellow Perch with 23% and the Walleye with 19%. Each interviewed angler returned home with an average of 5.45 fishes weighing around 2.2 kg. Fishing success and the size of fishes captured varied seasonally and geographically.

This report is full of interesting information. Several figures summarizing the biological characteristics (size, weight, etc.) of the captured fish species for each region and maps indicating the most visited (best?) area in each basin for the most sought after species are included.

The M.L.C.P. is to be commended for doing and publishing this study. Its realization must have entailed a great expenditure. Follow-up studies will have to be made in order to examine the evolution of the exploitative trend. However, to be useful, this information will have to be integrated in a broader management perspective. In the last 100 years, changes in the environment have been far too extensive and rapid for the ecosystem as a whole to absorb without deleterious effects, and for biologists to even begin to understand. To this day, wildlife management policies have centered mainly on the control of the human impact on the exploited natural resources (i.e. hunting and fishing regulations). More often than not, this has been done without a sound knowledge of the biology of the resources and of their place within the ecosystem as a whole. Research priorities must be reoriented toward this last endeavor if we want to develop more coherent and fruitful management policies.

On a more technical aspect, the publication is in the form of a stapled manuscript. The quality of the few photographs is below standard but the writing style and line diagrams are clear. A few misspellings were noted. Also, I fail to see the relevancy of publishing, even in a technical report, photocopies of computer printout showing results of statistical analyses. However, the fact that this report is free and that it provides a wealth of information about sport fishing in the Montreal area far outweigh these minor shortcomings.

FRANÇOIS CHAPLEAU

Department of Biology, University of Ottawa, Ottawa, Ontario K1N 6N5

Guide to the Otoliths of the Bony Fishes of the Northeast Atlantic

By Tero Härkönen. 1986. Danbiu ApS, Hellerup, Denmark. 256 pp., illus. U.S. $80.00.

This book is meant to be a guide for the identification of otoliths ("earstones") from fishes of northern European shores. Also included are several freshwater and anadromous species, about 15% of the total. It is not a taxonomic treatment. The author's interests are in the feeding habits of seals and cormorants, and faecal samples with their hard remains were the most convenient means of obtaining this information. A total of 103 fish species were examined for their otoliths and over a third of these are also found in Canadian waters.

The book comprises an introduction including the anatomy, function, composition, and growth of otoliths. An explanation is given on how otoliths are used in feeding analyses, including methods of estimating size of the fish consumed. Methods of preserving and treating otoliths are outlined. A key to families and species follows.

The main part of the text is 97 plates facing a text description of the species. Each plate may have up to six scanning micrographs of fish otoliths showing both the left and right sagitta usually in decreasing size and with "inside" and "outside" views. The text gives Latin, English, German, French, Swedish, and Danish names for each species, a general description of the otolith (only sagittae, the largest of the three otoliths in the fish labyrinth, are described), a sentence summarizing the most important characters, line drawings of the sagitta in lateral and dorsal view to indicate key features, and correlations between otolith length and body size based usually on a minimum of 30 specimens. The book concludes with 63 references and a short species index.

This book is useful for identification of sagittal otoliths where this is meant as a tool for other studies such as diet, archaeological investigations, and species and size composition analyses. It is not an exhaustive treatment of a particular fauna, such as that of northeastern Europe, since many otoliths are too small or too rare to figure significantly in the samples on which the author's primary work is based. Nevertheless, there is a stimulus here for others to develop a collection of scanning micrographs encompassing particular faunas or taxa. This would prove most useful for those interested in adding characters to systematic analyses or to those whose animals consume the smaller species of fish. For both identification and systematic works, it would have been most useful if a few species had been examined in large series including both sexes, all sizes, and distributions whether horizontal or vertical. Individual variation is difficult to estimate from a few micrographs which necessarily reflect an ideal state.

The text has a number of errors in spelling, including scientific names, and of arrangement although this does not appear excessive. For example, the key on page 45 refers the reader to Gadidae on page 146 but this page is occupied by Cottidae. A glossary of terms would have been useful. Colliculum is defined in the text and pops up in the keys but is not illustrated or indexed.

The most important part of this book to the user is the keys. Attempts on my inexperienced part to key out otoliths in a blind test indicate that this requires considerable practice, all the more so if the otoliths are broken or worn. Hence, the scanning micrographs, though of "perfect" specimens, are most valuable as they show structures in an almost three dimensional aspect. These micrographs make an otherwise highly-specialized book of potential use to workers in fields other than the author's and the book can be recommended on this basis.

BRIAN W. COAD

Ichthyology Section, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Biology of the Land Crabs

Edited by Warren W. Burggren and Brian R. McMahon. 1988. Cambridge University Press, New York. 479 pp., illus. U.S. $59.50.

Biology of the Land Crabs is a comprehensive evolutionary and comparative overview of the current state of knowledge of a diverse group of decapod crustaceans. The editors give a very broad definition for the land crabs: all anomuran and brachyuran crabs that, due to various types of adaptation, are active in air. It is clear that some of the contributing authors do not agree with the definition but all have complied with it.

Subjects included cover the range of evolution and zoogeography, ecology, behaviour, reproduction and growth, and the special physiological adaptations required for life out of water. Activities described include such fascinating topics as tree climbing, sound production, migration, response to predators, etc. The chapters are well coordinated, with cross references to other parts or chapters of the book. And although there are many areas of overlap, these are of subject matter not of focus: thus different aspects of reproduction are discussed under ecology, behaviour, and physiology. There is an appendix that briefly outlines the natural history of over eighty of the commoner terrestrial species, a list of references, and three indices (to authors, scientific names, and subjects).

I have rarely encountered such a cohesive multi-authored work so excellently edited. Its focus on the evolution of adaptations to life out of water make it of interest to more than just serious carcinologists, and I would recommend it to all who are studying terrestrial adaptation.

DIANA R. LAUBITZ

Zoology Division, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Analyses in Behavioral Ecology: A Manual for Lab and Field

By Luther Brown and Jerry F. Downhower. 1988. Sinauer Associates, Sunderland, Massachusetts. viii + 194 pp., illus. U.S. $12.95.

Behavioural ecology is a fast growing area of biology, appealing to researchers and students alike. For instructors in this subject, a guide to feasible projects serving as exercises for students would be a boon, and the present manual is designed to fill this almost vacant niche.

Twenty-seven topics are offered under the headings of sensory capabilities, feeding patterns, spacing patterns, and reproduction. The latter 85

pages provide a wide-ranging and admirable introduction to the statistical analysis of data, including visual presentation of data, circular statistics, and multidimensional G tests.

With the avowed hope that the approaches advocated should not only expand understanding, but also provide enjoyment, the presentation of each topic poses questions, outlines methodology for collecting relevant observations, indicates an interpretation, and includes references to the primary literature. A wide diversity of species (including insects, birds, rodents, and fish), behavioural situations, and analytical methods are laudably integrated into the projects, varying in logistical simplicity and seasonal availability. The adherence to legal and ethical standards is only implicit, but the warning of the possibility of allergies to bees is explicit.

Conceptually, the material incorporates some advanced issues such as the controversial mating advantage of rare males and the relation of sex ratios to local mate competition. For the proper presentation of these issues, instructors will need to do their homework. They will nonetheless welcome this book.

PATRICK COLGAN

Department of Biology, Queen's University at Kingston, Kingston, Ontario K7L 3N6

BOTANY

The Flora of the Tobermory Islands, Bruce Peninsula National Park

By J. K. Morton and Joan M. Venn. 1987. Biology Series No. 31. University of Waterloo, Waterloo. 92 pp., illus. $15.00

John Morton and Joan Venn have produced another in a series of floras for the Georgian Bay-Lake Huron region of south-central Ontario. This volume complements their earlier flora of Manitoulin Island and adjacent smaller islands (1984), and covers approximately 24 islands north of the tip of the Bruce Peninsula, many of which are now included within the new Bruce Peninsula National Park.

The total vascular plant flora of these islands stands at 542 species. The authors note that the species composition on a given island is subject to variation, due to factors such as changing water levels and movements of dispersal agents like gulls. The smaller shoals are particularly susceptible to these factors. These and other factors that have affected the past and present floristic composition of the study area are amply covered in the introductory sections of this book (Geology, Climate, Past Glacial History, Recent History, History of Botanical Exploration). A fairly detailed section on Vegetation and Ecology outlines the dominant and characteristic vascular plants found in the plant communities that have developed on these islands. Each of the major islands is described briefly, in terms of topography, substrates, and major plant communities. In general, these introductory sections provide a good context for understanding the flora of these islands. However, the section on geology is too repetitive. For example, the process of differential erosion is explained or mentioned four times in the span of less than one page. The phytogeographic affinities of members of the flora are briefly discussed in the introduction, as well. In this connection, I should point out a common error regarding the floristic affinity of Little Bluestem [*Andropogon (=Schizachyrium) scoparius*]. It is usually assumed to be a prairie species, as it is in this book, and it is true that this grass occurs in the tall-grass prairie of the mid-west. However, it is largely eastern in distribution, and is equally, if not more, abundant on the coastal plain of eastern North America. It can hardly be considered a prairie element, unless all coastal plain species are also placed in that category. I also consider Wood Millet (*Milium effusum*) to belong to the northern mixed forest flora, not to the eastern deciduous forest component, as defined by most phytogeographers. The floristic affinities of a few other species are up for debate.

A major portion of this book is devoted to an annotated listing of the flora. This is the important part of the book. Here, information on status and habitat are found. There are no real surprises in the species list, but the data included here will form an important database for park planning and future surveys of the islands for the purpose of monitoring change. The database function of this book is greatly enhanced by the tabular listing of the plants on each island. It seems odd, however, that the tabular listing is not in the same order as the main text. The plant families in the main text are arranged in the order found in *Gray's Manual of Botany*, Eighth edition (1950), whereas the checklist is largely alphabetical. I differ with an occasional synonym or taxonomic concept in this treatment, but in all such cases, these are matters of taxonomic opinion.

This flora is rounded out by a series of photographs (67) by Donald Gunn and John Morton. Many of these are of good to excellent quality. They represent only a small proportion of the species in the flora, but several species that are not commonly photographed are included, and of course, the photographs provide a colorful backdrop for the text.

There are two aspects of the production of this book that require mention. Firstly, the introductory sections (and to a lesser extent, the annotated flora) contain quite a few typographical errors. Secondly, the book is poorly bound. My copy has already fallen apart.

Although the area covered by this flora is small, this work still provides a valuable contribution to our knowledge of the distribution of species in Ontario. Hopefully, it will also provide valuable data for the planners and managers of the new national park in which these islands are contained.

WILLIAM J. CRINS

New York State Museum, Biological Survey, Albany, New York 12230

Lichens of the Ottawa Region (Second Edition)

By I. M. Brodo. 1988. Special Publication No. 3. Ottawa Field–Naturalists' Club, Ottawa. 115 pp., illus. $9.95 + $2.50 postage.

One of the long-standing burdens of amateur lichenology in Canada has been a general lack of keys to Canadian lichens. Among the first popular keys to appear in print in this country were those of Dr. Ernie Brodo, published in *Trail and Landscape* by the Ottawa Field–Naturalists' Club between 1967 and 1972. Later, in 1981, those keys were reassembled to book form as *Lichens of the Ottawa Region* (Syllogeus No. 29 of the National Museum of Natural Sciences).

The first edition of *Lichens of the Ottawa Region* was well received by the naturalist community (see for instance James Case's review in *The Canadian Field–Naturalist* 99: 286–287), and the demand for it soon exceeded the supply. Now, having been out of print for some years, Dr. Brodo's keys are available once again.

In its second edition, *Lichens of the Ottawa Region* has in many respects come out ahead. To begin with, the layout is now more attractive and, indeed, more "user friendly". Gone are the page-width lines of the introductory sections; in their place are double columns, much easier to read. Likewise, the print is now tighter and less shambling. But best of all, the spine-glued binding of the first edition (my copy has long since begun to fall apart) has been replaced by a plastic coil binding better suited to the extensive page-flipping it is "bound" to receive.

In his preface to the first edition, Dr. Brodo noted that a great deal more exploratory work was needed in the Ottawa area before the lichen flora could be said to have been adequately sampled. Seven years later, the second edition now adds no fewer than 28 new lichen species to the Ottawa flora, bringing the regional total to about 400. (Question: if new lichens can still be found by the dozen within 50 km of the National Museum of Canada, what mouth-watering discoveries await the collector in other parts of the country?)

A once-through of the text has turned up no obvious typographical errors or other glitches. For the most part, I find the word pictures painted by the keys to be lucid and easy to visualize. In the keys to the crustose species, however, the tattoo of technical jargon can at times be a little overwhelming — but this merely reflects the intense focus required in order to identify them. Fortunately, things are easier with the foliose and fruticose lichens; and even where they are not, there is always a well-appointed glossary to refer to, happily cross-referenced to some 84 illustrations.

The taxonomy is up-to-date and liberal. Most users will applaud Dr. Brodo's decision to adopt *Punctelia, Xanthoparmelia,* and other recent generic segregates of the classic genus *Parmelia.* This practice brings *Lichens of the Ottawa Region* in line with most other modern North American lichen references, including Mason Hale's *How to Know the Lichens.*

My only real criticism of this book has to do with its treatment of outdated lichen names, or synonyms. Although synonyms are legion in lichenology just now (lichen taxonomists have been working overtime during the past decade), they appear only in the index, where (even worse) they have been cross-referenced only in one direction, i.e. from the earlier name to the currently accepted one. In my opinion, Dr. Brodo would have done better to have at least included synonyms in the keys — if only to make life easier for those accustomed to the older taxonomies.

Best served by *Lichens of the Ottawa Region* are, of course, residents of the Ottawa area; it will also, however, be found useful for much of Ontario and Quebec, and applies with fair regularity even to the lichens of the west, especially the macrolichens. Clear, well-illustrated, comprehensive, and up-to-date, here is a book that has something worthwhile to say to Canadian lichen afficionados wherever they live.

TREVOR GOWARD

Edgewood Blue, Box 131, Clearwater, British Columbia V0E 1N0

A Second Checklist and Bibliography of the Lichens and Allied Fungi of British Columbia

By Willa J. Noble, Teuvo Ahti, George F. Otto, and Irwin M. Brodo. 1987. Syllogeus 61. National Museum of Natural Sciences, Ottawa K1A 0M8. 95 pp. Free.

In May of 1967, George Otto and Teuvo Ahti brought out a preliminary checklist of the lichens of British Columbia, listing some 569 species in 99 genera. Now, two decades later, a revised checklist has appeared, and here the totals have increased to 1 013 species (50 new to North America) in no fewer than 205 genera. Clearly, lichenology in the west has come of age.

The list is based largely upon herbarium specimens, though where no specimens were available the authors have made use of literature reports instead. Accepted taxa appear in bold face and are often accompanied by a brief notation on distribution. Doubtful records and synonyms are also included, the latter having been cross-referenced to the accepted names. The taxonomy is refreshingly up-to-date, and includes most of the segregate genera formerly included in, for example, *Lecanora, Lecidea, Parmelia,* and *Physcia.*

Another up-to-date feature of the checklist is its inclusion of lichen parasites and other allied non-lichenized fungi. Implicit in this practice is a recognition that the lichen life form is not so much a discrete biological or taxonomic unit, as a dietary preference of various fungi (for algae). Viewed from this perspective, lichenology is really just a fuzzy-edged subunit of mycology, and it is therefore not unreasonable that lichenologists should finally begin to study allied fungal groups. Twenty-two of these have been included in the present checklist, and it can be expected that many more will appear in future revisions.

Following the checklist is a comprehensive bibliography consisting of nearly 300 titles. Unfortunately, little attempt has been made to tie these references to the checklist itself, and so the user is seldom able to track down any particular entry to its source. A more helpful approach might have been to include at least one specimen citation or literature reference for each accepted entry. Admittedly, some of this information is already available in the original checklist, and some is to be found in Brodo's *Catalogue of Lichens* (1981). The former reference, however, is now largely out-of-date, and the latter has never been published.

For the most part, the text is admirably free of errors, though given the complexity of a work of this kind, it is not surprising that a few mistakes have inevitably crept in. Putting aside small points of punctuation and spelling, I note the following: 1) *Erioderma sorediatum* (p. 38) was never published in that genus, but appeared as *Leioderma sorediatum*, correctly listed on p. 48 (but note that the author citation should be Galloway and P. M. Joerg, and not P. M. Joerg and Galloway!); 2) *Leptogium cyanescens* (Ach.) Koerber (p. 49) should actually be cited as (Rabenh.) Koerber; 3) the inclusion of *Leptogium rivale* tuck. (p. 49) is based on a misidentified specimen of *Collema fecundum* Degel., and should be deleted from the list; 4) *Neofuscelia loxodes* (Nyl.) Essl. has been incorrectly listed as "*Melanelia" loxodes* (Nyl.) Essl. (p. 51); and 5) the "sinense" in *Parmotrema sinense* (Osbeck) Hale & Ahti (p. 58) should actually be spelled "chinense".

The *Second Checklist* is a major event in Canadian lichenology. Its publication is sure to inspire a closer look at one of the richer lichen floras in North America. Already, I am aware of some dozen species which have yet to be recorded for British Columbia, and doubtless there are hundreds more to come. The authors are to be congratulated on bringing out a work which will serve as a cornerstone of western lichenological research for years to come.

TREVOR GOWARD

Edgewood Blue, Box 131, Clearwater, British Columbia V0E 1N0

Mosses, Lichens and Ferns of Northwest North America

By Dale H. Vitt, Janet E. Marsh, and Robin B. Bovey. 1988. Lone Pine Publishing, Edmonton. 296 pp., illus. Cloth.

Every so often, a book appears which promises to introduce to the many a field of study which formerly has been the private domain of the academic few. *Mosses, Lichens and Ferns* may be just such a book. Or then again, it may not be. For the reviewer, it is something of a dilemma: on the one hand this field guide is at once attractive, authoritative, easy to use, and best of all, inexpensive; on the other hand, it can sometimes be vague, overly technical, poorly illustrated, and, worst of all, inaccurate.

The book opens in the expected way with a chapter introducing the reader to the study of cryptogams. Included here are a minicourse on the use of binomials, an overview of the climatic and

vegetation zones of western North America, and various notes on collecting, preserving, studying, and photographing the groups in question.

The body of the book is then given over to the species accounts, which are ranged in four chapters, including one on liverworts. The species coverage is fairly comprehensive, with 243 mosses discussed under 165 entries, 246 lichens under 155 entries, 40 liverworts under 20 entries, and 44 ferns under 28 entries. Each chapter opens with a succinct, but generally somewhat technical, overview, and is followed by a key to the species, also rather technical in the cases of the mosses and liverworts.

A nice touch are the habitat symbols appearing with each species account. These provide the reader with a quick idea of which species to look for where, and where to look for which species. Accompanying the symbols are range maps (very approximate) of the Northwest.

Closing the book are a bibliography, glossary, and index. The bibliography is reasonably thorough, and provides a brief summary of contents for each of the 60 references listed. The glossary is perhaps less helpful, owing to a complete absence of diagrams or even any cross references to the introductory sections. The index, though adequate, might have been made more accessible to the novice through the use of symbols denoting the group (i.e. mosses, hepatics, lichens or ferns) to which each species belongs.

The cover illustration is attractive, but not particularly well conceived. Where one might have expected, given the book's title, to find an illustration of a moss or lichen, one finds instead a photograph of a liverwort, *Conocephalum conicum*. Although liverworts do appear in the text, one must ask whether including a liverwort on the cover of a book which claims to be about mosses, lichens, and ferns is not likely to be a source of at least initial confusion for the reader/browser unacquainted with these groups.

Also rather puzzling is the inclusion of ferns in this book. Ferns, after all, are vascular plants and as such, already find adequate treatment in the standard floras, not to mention various popular guides, notably *How to Know the Ferns* by J. T. Mickel, and *Pacific Northwest Ferns and their Allies* by T. M. C. Taylor. Assuming that the authors' primary objective was to win wider currency for some of the less appreciated cryptogams, perhaps the Myxomycetes (slime moulds) would have been a more logical choice.

Accompanying the text are nearly 500 illustrations, of which more than 400 are in full colour. It is these latter which constitute the book's major strength, most being vibrant, legible, taxonomically revealing, and, not least, aesthetically satisfying. The only major exceptions are the dark-coloured species, for which the illustrations are at times entirely unhelpful. The photo of *Melanelia exasperatula* (p. 217), for example, is exasperatula in the extreme, as are the photos of *Andreaea rupestris* (p. 56) and *Atrichum undulatum* (p. 60). All of these might have been in part salvaged through the use of detailed line drawings.

Other illustrations miss the mark in different ways. Thus, the photo of *Athyrium filix-femina* (p. 272) has this forest-loving species growing in a boulder bed, while on page 273 the fronds of *Gymnocarpium dryopteris* are shown in a semi-dehydrated state quite atypical of their usual appearance. Among the bryophytes, several photos illustrate only the gametophyte, and thus completely ignore the often more diagnostic sporophytic characters. The sporophytes of *Hypnum circinale,* for example, readily separate this species from the otherwise similar *H. subimponens* (both p. 103), though only in the latter species are capsules illustrated.

It must be pointed out, moreover, that not all of the photos have been correctly labelled. For example, *"Dendroalsia abietina"* (p. 113, bottom right) should be corrected to *Rhytidiadelphus loreus, "Cladonia coniocraea"* (p. 199) to *C. sulphurina, "Cladonia scabriuscula"* (p. 208) to *C. amaurocraea, "Hypogymnia enteromorpha"* (p. 225) to *H. metaphysodes, "Peltigera rufescens"* (p. 230) to *P. ponojensis,* and *"P. polydactyla"* (p. 233) to *P. neopolydactyla.* Although the last of these could be said to represent simply a more conservative taxonomy on the part of the authors (in this case Janet Marsh) than on the part of the reviewer, Marsh would have done better to illustrate specimens whose morphology was central, not peripheral, to the species concept. Among the lichens, this last observation applies equally to the photos of *Cetraria canadensis* (p. 212), *Xanthoparmelia taractica* (p. 223), and *Hypogymnia imshaugii* (p. 226).

No less uneven than the illustrations are the written species accounts they accompany. These vary from rather good in many cases, to inexcusably vague in others. Much of the difficulty the novice will experience in using the descriptions stems from the fact that no attempt has been made to standardize them, even within a single group. This has made cross-checking for any given character most tedious, and in many cases impossible.

A special word of caution applies to the bryophytes. Because of their small size and often rather bewildering greenness, mosses and liverworts are perhaps intrinsically less easy to identify than other groups. The user of *Mosses, Lichens and Ferns* should not be discouraged if

many common bryophytes resist his best efforts with a hand lens. Notwithstanding the promises implicit in the keys and illustrations, final determination will in many cases still have to await critical examination under a microscope.

Evaluating a multiauthored, multidisciplinary work such as *Mosses, Lichens and Ferns* is not an easy task, and any summarizing comments are unlikely to hold across the board. However, it is probably fair to suggest that the many weaknesses and oversights noted above are artifacts of a book rushed into publication before its time. One can only hope that future editions will display a closer attention to detail. Only then is this book likely to become the epoch-making event it was obviously intended to be in the first place.

None of the above remarks, however, seriously detract from the fact that *Mosses, Lichens and Ferns* is already a handsome volume. As well as being the only book of its kind yet to have appeared for northwest North America, it is also, in most ways, a job well done. Trim, pocket-sized, and sturdily bound, here is a book that will be at home both in the field and, for the ardent, on the coffee table. Buy it.

TREVOR GOWARD

Edgewood Blue, box 131 Clearwater, British Columbia V0E 1N0

Illustrated Guide to Some Hornworts, Liverworts, and Mosses of Eastern Canada

by Robert R. Ireland and Gilda Bellio-Trucco. 1987. Syllogeus 62. National Museum of Natural Sciences, Ottawa. 205 pp., illus.

Attempts to produce popular guides to bryophytes are few. One of the major reasons is the importance of microscopic features to obtain critical identifications. It is possible, however, to determine many common bryophytes utilizing features visible to the naked eye and a simple 10-20x hand lens. The guide presented by Ireland and Bellio-Trucco, with the assistance of Linda M. Ley, gives eastern Canada a useful manual to determine nearly one-third of the bryophytes reported from that region. This area is defined by the authors to include southern Manitoba and all of the provinces east of that, but excludes many species that are common in the northern Territories and arctic environments in the eastern provinces.

The guide treats 235 species belonging to 90 genera of mosses, 43 genera of liverworts, and 2 genera of hornworts. The authors have chosen very carefully to include the bryophytes that are most likely to be encountered and that can be discriminated effectively using non-microscopic features. This means that they treat approximately 31% of the total flora. The guide is an introduction, and a very good one, produced by professionals who have comprehensive experience with these plants. Added to this, they are sensitive to non-professional users of the guide.

The guide is designed for a beginner with an interest in plants. A discussion is provided to present aspects of the life cycle, structure, collecting methods and preservation, and directions concerning identification through use of the guide. General keys lead the user to the major groups of bryophytes (hepatics, mosses, liverworts) and further keys for each of these groups guide the user to the names of genera and their species.

For most bryophytes, no popular English names are available, reflecting the general oversight of these plants by naturalists. For each species, the dichotomous key leads to a name, and this species name provides information concerning habitat, and abbreviated geographic distribution. For each species, a figure is given to present pertinent detail so that the identified specimen can be compared with the illustration. The user should be warned that bryophytes often include an intermixture of different species and even genera, therefore caution needs to be exercised. Furthermore, some bryophytes are somewhat plastic in their morphology, and may show variant forms related to the habitat conditions under which they grew.

A serious amateur will undoubtedly accept Dr. Ireland's generous offer to refer puzzling specimens to him. If so, a well labelled and prepared specimen should be provided.

The guide should encourage field naturalists to learn more about these attractive and intriguing plants that show such diversity in form and biology. The availability of this guide should encourage teachers to introduce these plants to students. For field naturalists, it opens up a new spectrum of plants of great interest.

I have discovered that copies of this publication are no longer available free of charge. This is more a reflection of current governmental policy concerning science than museum policy. The charge is apparently modest and adds postal charges.

W. B. SCHOFIELD

Department of Botany, University of British Columbia, Vancouver, British Columbia V6T 2B1

Mushrooms and Other Fungi of the Midcontinental United States

By D. M. Huffman, L. H. Tiffany, and G. Knaphus. 1989. Iowa State University Press, Ames, Iowa. 326 pp., illus. U.S. $19.95.

Another in a long line of handbooks for the beginning student of mushrooms and other large fungi. The proliferation of this type of book simply reflects the growing popularity of the subject. The handbooks specializing in specific regions are much needed.

This book is quite above the average. There are about 200 color pictures and all are a very good quality. I particularly like the format which has the color picture of the mushroom on the page facing the description and discussion of it.

The book has three principal sections. The introduction of 27 pages is very well written and illustrated to explain various features of mushrooms from hallucinogens to spore prints. The main text, of about 270 pages, is devoted to describing nearly 250 common species of mushrooms. Finally, there is a short glossary which will be an invaluable help to the beginner in understanding many of the characters of mushrooms. The primary name used for each mushroom is the scientific name which is, by tradition, in Latin. Well-known common names are also included and happily the authors did not propose or dream-up common names for those mushrooms which lack them (as some recent field guides have done, with the amusing result we have a series of "common names" which have never been used before, such as "Pumpkin Ringstalk", and seem nonsensical).

As pleased as I am with this manual, there are a few minor lapses that I want users to note. The species of *Hericium* on pages 213-215, are confused. Figure 137 is *H. ramosum* but the description is of *H. coralloides*, Figure 138 is *H. coralloides* and Figure 6B is more my idea of *H. erinaceus*. Although the spores of *Ganoderma applanatum* may appear to have "minute spines", the ornamentation of the basidiospore walls is due to pitting of the thick brown wall. The spore print color for *Ganoderma lucidum* is brown, not white as stated. *Phellinus igniarius* causes a white rot, not a brown rot as stated. In my experience, *Piptoporus betulinus* fruits only on dead trees or dead branches and stems of live trees, not on live trees as stated. The name of one of the authors for *Polyporus alveolaris* is abbreviated Bond., not Bord.

A fine little book which I do not hesitate to recommend. Canadians should not by-pass this book because of its title, nearly all the species can be found in most parts of southern Canada.

J. GINNS

Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario K1A 0C6

How to Identify Mushrooms to Genus VI: Modern Genera

By D. L. Largent and T. J. Baroni. 1988. Mad River Press, Eureka, California. 277 pp. U.S. $22.95.

This is the sixth in this interesting series designed to facilitate identifications of mushrooms by students and serious amateurs. This volume contains two complete sets of keys to the genera of gilled mushrooms, one emphasizing macroscopic features (part III), and the other microscopic features (part I). Boletes and other fleshy fungi lacking gills are excluded. An excellent idea was the inclusion of additional specialized keys to genera in restricted habitats or on unusual substrates, i.e. dung, greenhouses, burn sites, conifer cones, *Sphagnum*, other mosses, parasitized mushrooms, and dunes (part V). There are no illustrations, but reference to illustrations in earlier volumes is included.

One is tempted to compare this book with Rolf Singer's monographic treatment of mushroom genera (see review, *Canadian Field-Naturalist* 102: 402-403, 1988); however, they are not written at the same level. While this volume will undoubtedly be very useful as an intermediate teaching tool between the use of popular guides and Singer's monograph, there are many areas where improvements could be made before a second printing. The parameters for the scope of the book are not given. It appears to encompass most temperate North American and European mushroom genera. The endemic European genera *Geopetalum, Haasiella,* and *Leucocortinarius* are included. However, all endemic southern hemisphere genera are lacking, as are Asian genera such as *Lampteromyces*, and genera reaching both Asia and North America from the south, e.g. *Descolea* and *Termitomyces* in Asia, and *Pyrrhoglossum, Ripartitella* and *Smithiomyces* in North America.

Nearly all genera treated in the keys are described in part II, but *Plicaturopsis* in the macroscopic based key, part III, is not treated. For most genera, brief descriptions of macroscopic and microscopic features are given, along with selected

references to published species keys and illustrations. The list of published keys is not as complete or as up to date as it could have been. Examples of missing keys are *Hygrophorus* by Bird and Grund (*Proceedings of the Nova Scotia Institute of Science* 29: 1–131, 1979), *Hydropus* by Singer (*Flora Neotropica* 32, 1982), *Phaeocollybia* by Horak (*Sydowia* 29: 28-70, 1977), *Hohenbuehelia* and *Resupinatus* by Thorn (*Mycotaxon* 25: 321–453, 1986), and *Cortinarius* subgenus *Bulbopodium* by Smith (*Bulletin of the Torrey Botanical Club* 69: 44–64, 1942).

Comments on the status of acceptance of each genus and other features are also given. In many cases, it is not clear if the authors themselves accept certain genera, or whether only one of the authors accepts a genus. Generic coverage, either as accepted genera or as synonyms, is not complete, even for temperate North America. No mention is made of several genera present in North America proposed within the last 20 years, e.g. *Megacollybia* 1972, *Cantharocybe* 1973, *Caulorhiza* and *Gammundia* 1979, *Resinomycena* 1981, *Neolentinus* and *Ossicaulis* 1985, and *Mythicomyces* and *Stagnicola* 1986, nor of some of the more unusual genera such as *Campanella*, or recently resurrected genera e.g. *Lentinula* and *Tapinella*.

Several errors were noted in the keys and text. In part I, *Phaeogalera*, a genus with germ pores, cannot be keyed out to the Cortinariaceae, the family to which it is assigned. Similarly, *Pseudobaeospora* with its attached lamellae, cannot be keyed to the Lepiotaceae. Species of *Arrhenia* which the authors treat as *Leptoglossum*, with subglobose to lacrymoid spores, cannot be keyed to either genus. Reference to Watling (1979) on page 115, evidently refers to Orton and Watling (1979), and the two statements regarding generic recognition attributed to Watling 1979 are contradictory for *Pseudocoprinus* on that page. Also, contrary to statements in the text, some *Galerina* species lack plages, some *Marasmiellus* species form rhizomorphs, and, worldwide, there is more than one species of *Cyphellostereum*.

Notwithstanding the problems discussed above, do I recommend this book to students and serious amateurs? The answer is yes. Used as a teaching tool with some modifications, it will be very useful and it contains a lot of helpful hints and information. The multiple keys offer students and amateurs different options and even where there appears to be a problem in one key, the genus can often be reached in another or in the tables given on pages 140-153. For those who wish to acquaint themselves with many of the modern genera, this publication is a bargain compared to purchasing more technical manuals, and therefore fills a much needed gap in the literature. Final words of advice to the authors: move the index to the back of the book, index the generic names in the keys, and make the book comprehensive for a defined geographic area.

S. A. REDHEAD

Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario K1A 0C6

ENVIRONMENT

Stones of Silence — Journeys in the Himalaya

By George B. Schaller. 1988. Originally published by Viking Press, 1980. University of Chicago Press, Chicago. 292 pp., illus. U.S. $14.95.

As the director of science for the New York Zoological Society, George Schaller has roamed the globe studying the ecological and evolutionary relationships of some of the world's more glamorous larger mammals including gorillas and lions in Africa, tigers in India, pandas in China, and wild sheep goats in the Himalaya. The results of these studies have been published in such titles as *The Serengeti Lion* which received the National Book Award for science in 1972.

His reprinted book, *Stones of Silence*, is a complementary volume to his previous scientific monologue, *Mountain Monarchs*, which is a summary of his research on the ecology and behavior of Himalayan wild sheep and goats. *Mountain Monarchs* is written for those who want only the "facts". *Stones of Silence* is a more lyrical description of his journeys in Pakistan, India, and Nepal while conducting the research which lead to the publication of *Mountain Monarchs*.

While not a scientific treatise, *Stones of Silence*, is nevertheless full of detailed natural history observations as well as descriptions of his encounters with the land and its people. It is the richness of these descriptions which makes the book a first class adventure story as much as a valuable contribution to science.

Unlike most scientists, Schaller is an able writer and story teller. *Stones of Silence* shines with evocative images of the landscape and the people. For example, when Schaller talks about the hugiene habits of Tibetans, instead of saying the functional "they were dirty", he writes "Tibetans

do not wash unnecessarily". In another, he relates how he had to observe burial in Pakistan with a body guard to protect him from outlaws. However, he found it distracting to do his work "while someone behind me played restlessly with the bolt of his rifle." While cautiously working his way along an ice covered ledge in a narrow gorge, he momentarily forgets the dangers when rounding a corner and he observes ". . . a twenty-foot waterfall, a magic falls whose tumbling waters have been turned to clear shining glass."

Yet, the overall message of the book is not about the beauty of this mountain region as much as it relates in graphic detail the rapid destruction of the Himalaya flora and fauna as a result of an exponentially expanding human population. The title, *Stones of Silence*, poetically refers to what Schaller believes is the fate of the Himalaya. He is accutely aware that he is witnessing an ecological tragedy — a "great dying" as he calls it — happening right before his eyes and how the people of the region are as much victims as they are perpetrators of this impending disaster. He described the plight of a forest guard who was supposed to prevent timber harvest and hunting in a government preserve. Schaller says he saw the "vulnerable look of a quiet despair, the eyes of a man whose aspirations have been crushed by the world's indifference. He could not support his family, he told us, not on the one hundred rupees a month the government paid him. To survive he had to cut and sell the trees he was supposed to protect and he had to act as guide to illegal hunters . . ." Yet, Schaller does not condemn the man. Later he says "he was a good guide and an honest man, his destiny made tragic by fate."

In essense, *Stones of Silence* is a metaphor for what is happening to the entire Earth, not just the Himalaya as human pressures continue to destroy the world's ecosystems and simplify the rich diversity of life they support. Schaller feels that once the region's diverse and abundant wildlife is exterminated and extinct, the magnificent mountains will remain, but they will be cold, silent places, with the warmth of life extinguished.

Schaller includes the human element as part of this tragedy as well. After seeing some crude rock pictures of ibex and wolves near one village where human destruction of the mountain flora and wildlife was proceeding at a rapid rate, Schaller writes "When the huts of Besti have turned to dust and the last ibex has vanished into the belly of a hunter, these petroglyphs will remain speaking of the past in a silent voice to silent hills."

Schaller's book is an adventure story, a natural history story, and a conservation story wrapped up in one volume. *Stones of Silence* is a book worth reading.

GEORGE WUERTHNER

P.O. Box 273, Livingston, Montana 59047

Fire in America: A Cultural History of Wildland and Rural Fire

By Stephen J. Pyne. 1988. (Reprint of 1982 edition). Princeton University Press, Princeton. 655 pp., illus. U.S. $14.95.

Stephen J. Pyne is a former fire fighter turned history professor who has taken on the exhaustive task of trying to write the definitive work on the relationship of humans and wild fires — particularly as it applies to North America. Pyne largely succeeds.

His comprehensive book, *Fire in America*, is well researched and documented. Introductory chapters on fire behavior and fire ecology give readers a rudimentary understanding of how fire influences the environment. Separate chapters on the regional fire histories of the Pacific Northwest, Southwest, Northern Rockies, Southeast, Alaska, Lake States, and California are included.

Intermixed with these regional historical reviews are chapters which document the use of wildfire by North American Indian, early European colonists and the pioneers who moved westward into the Lake States and on to the grasslands beyond. This fire-human relationship was largely one of mutual benefit. Fires created environments favorable to human hunting, gathering, and agricultural practices and as a result, humans purposely set fires.

The attitude of using or co-existing with fire which punctured the human-fire relationship for centuries began to change to control and suppression in the late 1800s. According to Pyne, the newly created U.S. Forest Service, established in 1905, seized wildfire suppression as a means of expanding its power and making itself indispensable to society. Under Forest Service guidance, coordinated federal fire suppression began and Pyne then traces the development of fire suppression, lead by the Forest Service, among federal and state agencies between the 1920s through the 1970s.

In his final chapters, Pyne outlines how scientific research on fire ecology during the 1970s has brought human attitudes about wild fire full circle and resulted in the adoption of a more tolerant view.

The standard doctrine that the only good fire was a dead fire was largely replaced — at least in the scientific community — by a perspective which sees fire as an essential ecological component of many ecosystems. This change in the scientific community paved the way for a change in federal fire policy to allow at least some fires to burn unhindered.

Reading Pyne's book gives one the sense that humans coevolved with wildfire, that we are, like the Lodgepole Pine, a fire-adapted species. Most human development and evolution took place in regions where periodic wildfires were the norm. Our dependence upon fire-adapted or fire-tolerant plant and animal communities caused humans to aid the expansion of fire's geographic influence by our propensity to set ignitions. Just as fire's natural geographic influence expands, so did the natural range of the human species. Without fire, would Ice Age hunters have ever pushed northward into Europe or cross the Bering Land Bridge? Reading Pyne, one begins to wonder if, along with the development of speech, and weapons, the partnership with fire might not also have been a major influence upon our present evolutionary course on earth.

Though such questions should be of interest to more than just those interested in fire history and ecology, this title is not likely to find its way to the best seller list. The book's completeness is also one of its major drawbacks. It takes quite a commitment of time to read and digest all the information presented. In addition, chapter organization is somewhat confusing. Each one is seemingly separate from the one before and after. As a result, there is often repetition of the same information in different chapters. However, this only becomes readily noticeable if one reads the book cover to cover in a single sitting.

Despite these minor shortcomings, Pyne's *Fire in America* is fascinating reading, not only for its completeness but the historical perspective it brings to today's land management issues. It deserves a reading by anyone interested in wildfire and its role, not only in natural history, but in human history as well.

GEORGE WUERTHNER

P.O. Box 273, Livingston, Montana 59047

Symbiosis: An Introduction to Biological Association

By Vernon Ahmadjian and Surindar Paracer. 1986. University Press of New England, Hanover, New Hampshire. 212 pp., illus. U.S. $32.50.

According to the authors, this book is primarily an introductory text designed for "students, instructors, and research workers who wish to learn more about symbiosis". I would argue that there is something here also for the naturalist. Seldom has the thesis that all living things are interconnected been so broadly and so cogently documented.

Symbiosis: An Introduction to Biological Associations has obviously been written from a conviction that the concept of symbiosis has not yet received due recognition as one of the unifying principles of biology. According to Ahmadjian and Paracer, "some of the greatest events in biological history, including the origin of the eukaryotic cell, as well as the most devastating diseases of mankind, are the results of symbiotic relationships".

The book is divided into thirteen chapters, the first of which opens with a most readable introduction. In it, the authors defend their preference for an inclusive definition of symbiosis, arguing that that is how the term was originally used by Anton de Bary, the German mycologist who coined it in 1879. To de Bary, a symbiotic association was not (as it is generally understood today) always one in which both partners benefit; rather it was simply a long-term living together of unlike organisms — without regard for the details of the relationship. As thus defined, symbiosis encompasses the entire spectrum of interspecific associations, from parasitism (one partner benefits at the expense of the other), through mutualism (both partners benefit), to commensalism (one partner benefits while the other is unaffected).

Such a broad definition allows the authors to range freely over every major branch of biology, there being no organism which does *not* enter into a symbiotic association of one kind or another. A simple listing of the major chapter heads reveals the breadth of this book: Viral Symbiotic Associations; Bacterial Associations; Symbiosis and the Origin of the Eukaryotic Cell; Fungal Associations; Protoctistan Symbiotic Associations; Helminthic Associations; Plant Symbiotic Associations; Behavioural and Social Symbioses; and, to round things out, Symbiosis and Evolution.

Each of the above topics is discussed in typical textbook fashion, with an emphasis on brevity, but usually with no corresponding loss of readability. Throughout the book, the chapters follow a standard format. After a brief introduction to the discipline in question, the authors present a

biological collage in which various symbiotic relationships are illustrated by specific examples. Closing each chapter is a summary of the main points discussed, followed by a suite of well-articulated review questions, and then followed again by a two-part bibliogrpahy — the first a list of recommended readings, and the second a listing of the more technical literature upon which the chapter was based.

Scattered throughout the book are a half dozen "box essays", in which the authors present, in popular fashion, various side themes of symbiosis. If these were intended to maintain reader interest, I can report that they work very well; perhaps space will be found in future editions to incorporate more of them.

One distracting feature of this book is the quite uneven levels of presentation. Getting through the chapter on viral symbiotic associations, for example, will probably be a real challenge for the amateur naturalist. On the other hand, the introduction to the chapter on fungal associations reads almost as a junior high school science text. Stylistic discrepancies can also be pointed out, though perhaps this is unavoidable in a team-written book of this kind.

Putting aside these small points of criticism, *Symbiosis: An Introduction to Biological Associations* is a fascinating read. Because the authors have undertaken to paint an enormous canvas, and because they paint from a perspective unfamiliar to most readers, the pictures they present are sure to amaze again and again. Did you know, for example, that:

— A heavy infestation of *Giardia* (Beaver Fever) can result in the production of more than 14 billion cysts per day?
— England's White Cliffs of Dover consist entirely of the fossil remains of foraminiferan amoebae?
— Trees infected with invading pathogens react by cordoning off the infected areas from the rest of the tree?
— Indian Pipe derives part of its nutrient requirements from trees through a sort of fungal straw?
— Three out of every four people on earth are infected with internal parasites?

Now that this book exists, I would not be without it. If only as a springboard to the vast and fascinating literature which surrounds one of the primary unifying principles of life, *Symbiosis: An Introduction to Biological Associations* is a valuable addition to any naturalist's library.

TREVOR GOWARD

Edgewood Blue, Box 131, Clearwater, British Columbia V0E 1N0

Population Ecology of Individuals

By Adam Lomnicki. 1988. Monographs of Population Biology, 26. Princeton University Press, Princeton, New Jersey. 223 p., illus. Cloth U.S. $52; paper U.S. $16.

Most classic population biology models assume no variation between individuals of a population. The population is assumed to be composed of homogeneous units. Lomnicki challenges this assumption. Then, he demonstrates how variation between individuals can lead to population stability and ultimately ecosystem stability.

Using graphs and mathematical models to illustrate his points, Lomnicki shows how population stability could result from two mechanisms: unequal resource partitioning between individuals and contest competition among individuals. Unequal resource partitioning results from phenotypic variations between individuals that cause differences in resource acquisition abilities. Differences in these abilities result in contest competition if the resource intake of the larger individuals is not affected by the resource intake of the smaller individuals. The example of contest competition given in this book was competition between trees for light. The tallest trees in a forest are able to acquire light without interference from the shortest trees; however, the light interception by the tallest trees reduces the quantity of light acquired by the shortest trees.

Obviously, the quantity of resources that an individual acquires is a function of its rank within a population. Individuals of the highest ranks often acquire resources in greater quantities than the resource levels required for reproduction and maintenance. Individuals of lower ranks may acquire resources between the resource thresholds for maintenance and reproduction or even below the threshold for maintenance. Individuals acquiring resources below the reproduction threshold will not reproduce, and individuals acquiring resources below the maintenance level will not survive long if they remain in the population. Often, the only alternative for these last two groups is to emigrate.

Lomnicki shows how emigration could cause self regulation of a population. He also shows how perception of a low probability of successful reproduction by low ranking individuals could force

their emigration out of a population in order to avoid certain reproductive failure in spite of the often low probabilities of finding enough unclaimed resources in other populations to meet their reproduction requirements. This form of self regulation often leaves the population at a level lower than the maximum number of individuals that its habitat could support.

This book will appeal to all advanced students, scientists, and professionals interested in population dynamics. The mathematical models presented in this book are relatively simple to follow. Only a rudimentary understanding of calculus is required to understand these models. Lomnicki uses these models to explore some new areas of theoretical cology where empirical evidence is not always available. Although Lomnicki has done his best to use empirical examples, this book's content is largely theoretical. However, this author's writing style makes this book very accessible to a wide audience of biologists.

BLAINE H. M. MOOERS

141 E. Miller, Apt. #6, Sidney, Montana 59270

Wetlands of Canada

By the National Wetlands Working Group, Canada Committee on Ecological Classification. 1988. Environment Canada (distributed by Polyscience, Montreal). xiv + 452 pp., illus. $56.00.

This is a most attractive book. It has an abundance of black-and-white photographs and well-drawn diagrams. Most of the authors write clearly. Everybody interested in this country's wetlands will find the chapter dealing with their own region absorbing. Therefore, the book deserves the attention of nearly all serious amateur naturalists, since all of them (surely?) find wetlands fascinating; but probably few will want to buy so hefty a book, covering the wetlands of all Canada.

It is the work of 33 contributors, whose affiliations are: 25 from assorted federal and provincial Government departments; 4 from ecological consulting firms; and 4 from universities. Between them, they have written 10 chapters and an appendix.

The appendix should be read first. It is by a committee of 13 of the contributors who present a three-level taxonomy of wetlands. At the highest level are Classes, of which there are 5 (bogs, fens, swamps, marshes, and open water). Next come Forms, for a total (in all classes) of 70. Lastly come Types, of which there are 16 (on two hierarchical levels). None of the forms is represented by more than a few possible types, so (fortunately) there are fewer than 1120 ultimate taxa.

After an introductory chapter, Chapters 2 to 9 give descriptions of the various wetland taxa in each of the 8 Wetland Regions (all with subregions) into which Canada is divided. These descriptions are all examples (admittedly, good ones) of classical descriptive ecology of the kind that prevailed 40 or 50 years ago. Most are a pleasure to read, and they impart plenty of information. But it is rather like listening to a running commentary on the Stanley Cup Final on radio instead of switching on the TV. The descriptions of vegetation must be based on data sets that cry out for modern methods of multivariate data analysis, that is, for well-chosen classifications and ordinations, but there isn't a sign of them. Three (only) of the chapters have diagrams showing the putative successional relationships among the different wetland taxa in a region. How interesting it would be to see ordinations of the data on which these diagrams are based! It is not as if such a treatment would be too technical for the intended readership: the book abounds with exceedingly detailed tables giving the results of chemical analyses of peat and water samples from particular wetlands.

The indexes are inadequate. There should have been an index to plant species and another to geographic locations, as well as the rather sketchy general index.

There is a glossary, and it cites the sources of its definitions. Perhaps it is unfair to quote the single embarrassing howler: "AUTOTROPHIC: Capable of deriving energy for life processes from the oxidation of inorganic materials (Agriculture Canada 1976)." Agriculture Canada should be ashamed.

It *is* fair to end on a positive note, however. The book has many virtues and its faults can be put right in promised future editions. One obvious way to improve it would be to invite more contributions from research workers in the academic world.

E. C. PIELOU

RR1, Denman Island, British Columbia V0R 1T0

MISCELLANEOUS

The Outermost House

By Henry Beston. 1988. (Reprint of 1928 edition). Penguin, New York. xxiv + 222 pp. U.S. $6.95; $9.95 in Canada.

The Outermost House, Henry Beston's account of a year at Cape Cod, is the latest instalment in the Penguin Nature Library series. An instant success at the time of its 1928 publication, the book went through several reprintings and has now been issued in paperback with an introduction by Robert Finch.

The Finch introduction provides information about Beston's life and career, explains the circumstances behind the writing of the book, and discusses the style and literary merits of the text. The reader learns that Beston originally built his cottage at Cape Cod, named Fo'castle, strictly as a summer retreat but decided to stay on over the winter of 1926-27 because he believed that the atmosphere would help his writing. The result of his enforced exile were several notebooks filled with observations and thoughts, which were then transformed, at the insistence of his fiancée, into *The Outermost House*.

Although Beston liked to describe himself as a writer-naturalist, Finch's introduction suggests that *The Outermost House* was largely an exercise in creative writing rather than the musings of a naturalist. At the same time, Finch notes that Beston wonderfully captures the rhythmic quality of life at Cape Cod, including the seasonal rituals. Unfortunately, Finch does not take his analysis far enough to explain why *The Outermost House* became an inspirational piece for the conservation movement of the 1960s. Perhaps, this is best left to Beston himself who in the powerful closing pages of the book warns: "Whatever attitude to human existence you fashion for yourself, know it is valid only if it be the shadow of an attitude to Nature. A human life, so often likened to be a spectacle upon a stage, is more justly a ritual . . . do no dishonour to the earth lest you dishonour the spirit of man . . . For the gifts of life are the earth's and they are given to all . . ." (pages 222-223).

W. A. WAISER

Department of History, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

NEW TITLES

Zoology

Advances in comparative and environmental physiology, volume 4: animal adaptation to cold. 1989. Edited by R. Gilles, C. P. Mangum, G. N. Somero, K. Takahashi, and R. E. Weber. Springer-Verlag, New York. c450 pp., illus. U.S.$113.

†**Alaska whales and whaling.** 1988. By Alaska Geographic, Anchorage. Reprint of 1978 issue. 144 pp., illus. + poster. U.S.$19.95; $23.35 in Canada.

American warblers: an ecological and behavioral perspective. 1989. By Douglas H. Morse. Harvard University Press, Cambridge. 384 pp., illus. cU.S.$30.

The application of remote sensing technology to marine fisheries: an introductory manual. 1988. By M. J. A. Butler. FAO, Rome. xviii + 165 pp., illus. U.S.$18.

Arabian mammals: a natural history. 1989. By Jonathan Kingdon. Academic Press, San Diego. 300 pp. cU.S.$130.

***Attracting backyard wildlife: a guide for nature-lovers.** 1989. By Bill Merilees. Whitecap Books. Vancouver. xvi + 159 pp., illus. $12.95.

***Audubon wildlife report 1989/1990.** 1989. Edited by William J. Chandler. Academic Press, San Diego. c540 pp. cU.S.$39.95.

†**The bamboo bears: the life and troubled times of the giant panda.** 1989. By Clive Roots. Hyperion Press, Winnipeg. x + 102 pp., illus. $23.95.

***Bear-people conflicts.** 1989. Edited by Marianne Bromley. Proceedings of a conference, Yellowknife, 6-10 April 1987. Northwest Territories Department of Renewable Resources, Yellowknife. 246 pp., illus.

***A bibliography of British Columbia ornithology, volume 2.** 1988. By R. Wayne Campbell, Tracey D. Hooper, and Neil K. Dawe. Heritage Record No. 19, Royal British Columbia Museum. Crown Publications, Victoria. 591 pp. $30.

***Birds in Ireland.** 1989. By Clive B. Hutchinson. Irish Wildlife Conservancy (distributed by Buteo, Vermillion, South Dakota). 215 pp., illus. U.S.$55.

***The butterflies of Manitoba.** 1989. By Paul Klassen, Richard Westwood, Bill Preston, and Brian McKillop. Manitoba Museum of Man and Nature, Winnipeg. vi + 290 pp., illus. $21.95 plus $2 postage.

A dictionary of ethology. 1989. By Klaus Immel Mann and Colin Beer. Harvard University Press, Cambridge. iii + 335 pp., illus. U.S.$35.

*__Dispersal in rodents: a resident fitness hypothesis.__ 1989. By Paul K. Anderson. Special Publication No. 9, American Society of Mammalogists, c/o H. Duane Smith, Brigham Young University, Provo, Utah. viii + 141 pp.

*__Eastern/central birding by ear: a guide to bird song identification.__ 1989. By Richard K. Walton and Robert W. Lawson. Peterson Field Guides. Houghton Mifflin (distributed by Thomas Allen, Markham, Ontario). 64 pp., illus. + 3 tapes.

__Ecological and behavioral methods for the study of bats.__ 1988. Edited by Thomas H. Kunz. Smithsonian Institute Press, Washington. xxii + 533 pp., illus. U.S.$50.

__Endangered animals.__ 1988. By Malcolm Penny. Bookwright, New York. 32 pp., illus. U.S.$11.90.

*__Fishes of the Thunder Bay area of Ontario: a guide for identifying and locating the local fish fauna.__ 1989. By Connie Hartviksen and Walter Momot. Wildwood Press, Thunder Bay. Illus. $24.95.

__Fish to reptiles.__ 1988. By Lionel Binder. Gloucester, New York. 36 pp., illus. U.S.$11.40.

__Frozen fauna of the mammoth steppe: the story of Blue Babe.__ 1989. By R. Dale Guthrie. University of Chicago Press, Chicago. c360 pp., illus. Cloth cU.S.$40; paper cU.S.$16.95.

__Guide to the mammals of Salta Province, Argentina.__ 1989. By Michael A. Mares, Ricardo A. Ojeda, and Ruben M. Barquez. University of Oklahoma Press, Norman. 320 pp., illus. U.S.$29.50.

__Introduction to forest and shade tree insects.__ 1989. By Pedro Barbosa and Michael R. Wagner. Academic Press, San Diego. 637 pp. U.S.$59.95.

__The loon: voice to the wilderness.__ 1988. By Charlene W. Billings. Dodd, Mead, New York. 48 pp., illus. U.S.$11.95.

†__Mammals of Oklahoma.__ 1989. By William Caire, Jack D. Tyler, Bryan P. Glass, and Michael A. Mares. University of Oklahoma Press, Norman. 544 pp., illus. U.S.$29.95.

*__The nature of birds.__ 1988. By Adrian Forsyth. Camden House, Camden East, Ontario. 160 pp., illus. $19.95.

__The new dinosaurs: an alternative evolution.__ 1988. By Dougal Dixon. Salem House, Topsfield, Massachusetts. 120 pp., illus. U.S.$19.95.

†__Oklahoma herpetology: an annotated bibiography.__ 1989. By Charles C. Carpenter and James J. Krupa. University of Oklahoma Press, Norman. 272 pp. U.S.$21.95.

*__On the track of ice age mammals.__ 1986. By Anthony J. Sutcliffe. Harvard University Press, Cambridge. 224 pp., illus. Cloth U.S.$25; paper U.S.$12.95.

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†__The reintroduction of the white-tailed sea eagle to Scotland: 1975-1987.__ 1988. By John A. Love. Nature Conservancy Council, Peterborough, Great Britain. 48 pp., illus.

__Shallow-water hydroids of Bermuda: the Athecatae.__ 1988. By Dale R. Calder. Royal Ontario Museum, Toronto. 107 pp., illus. $24.50.

__The short-tailed fruit bat: a study in plant-animal interactions.__ 1988. By Theodore H. Fleming. University of Chicago Press, Chicago. xvi + 365 pp., illus. U.S.$49.95.

*__Snakes of eastern North America.__ 1989. By Carl H. Ernst and Roger W. Barbour. George Mason University Press (distributed by University Publishing Associates, Lanham, Maryland). 282 pp., illus. + plates. U.S.$62.50.

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__The structure of the call note system of the warbling vireo.__ 1989. By Daryl Howes-Jones and Jon C. Barlow. Life Sciences Contributions 151. Royal Ontario Museum, Toronto. 40 pp., illus. $10.25.

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*__Turtles of the world.__ 1989. By Carl H. Ernst and Roger W. Barbour. Smithsonian Institute Press, Washington. 290 pp., illus. U.S.$45.

__Whale nation.__ 1988. By Heathcote Williams. Crown, New York. 191 pp., illus. U.S.$25.

†__Wildlife and man in Texas: environmental change and conservation.__ 1989. By Robin W. Doughty. Texas A and M University Press, College Station. 268 pp., illus. U.S.$12.95.

Botany

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__Aspects of floral development.__ 1988. Edited by Peter Leins, Shirley C. Tucker, and Peter K. Endress. J. Cramer in der Gebruder Borntraeger, Stuttgart. vii + 239 pp., illus. DM120.

__Atlas florae Europaeae, volume 3: distribution of vascular plants in Europe: Caryophyllaceae.__ 1989. Edited by J. Jalas and J. Suominen. Cambridge University Press, New York. 405 pp. U.S.$89.50.

The biology and utilization of shrubs. 1988. Edited by Cyrus M. McKell. Academic Press, San Diego. 656 pp. U.S.$125.

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The conspectus of bryological taxonomic literature, Part 1: index to monographs and regional reviews; and **part 2: guide to national and regional literature.** 1988 and 1989. By S. W. Greene and A. J. Harrington. J. Cramer in der Gebruder Borntraeger Verlag, Stuttgart. 272 pp. and 322 pp. DM 120 each.

Diatoms. 1989. By F. E. Round, R. M. Crawford, and D. G. Mann. Cambridge University Press, New York. c550 pp., illus cU.S.$150.

†**Discovering wild plants: Alaska, western Canada, the northwest.** 1989. By Janice J. Schofield. Alaska Northwest, Edmonds, Washington. c350 pp., illus. U.S.$34.95; $43.95 in Canada.

†**The ecology of intercropping.** 1989. By John Vandermeer. Cambridge University Press, New York. xi + 237 pp., illus. U.S.$59.50.

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Environmental stress in plants. 1989. Edited by J. H. Cherry. Springer-Verlag, New York. viii + 369 pp., illus. cU.S.$107.50.

*__The genus *Vaccinium* in North America.__ 1989. By S. P. Vander Kloet. Agriculture Canada. Canadian Government Publishing Centre, Ottawa. 203 pp., illus. $46.50 in Canada; U.S.$55.80 elsewhere plus $2.25 shipping.

Grass: systematics and evolution. 1988. Edited by Thomas R. Soderstrom, et al. Smithsonian Institute Press, Washington. xiv + 473 pp., illus. U.S.$45.

The Hepaticae of southern Greenland. 1989. By Rudolf M. Schuster. J. Cramer in der Gebruder Borntraeger Verlag, Stuttgart. 254 pp., illus. DM 170.

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*__Plants of Riding Mountain National Park, Manitoba.__ 1989. By William J. Cody. Agriculture Canada. Canadian Government Publishing Centre, Ottawa. 319 pp., illus. $24.75 in Canada; U.S.$29.70 elsewhere plus $1.90 shipping.

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Tropical forests and botanical diversity. 1989. Edited by L. B. Holm-Nielson, H. Balslev, and I. Nelson. Academic Press (Harcourt Brace Jovanovich, San Diego). 400 pp. cU.S.$49.50.

Vascular epiphytes: general biology and related biota. 1989. By David H. Benzing. Cambridge University Press, New York. 320 pp., illus. cU.S.$42.50.

Vegetation mapping. 1988. Edited by A. W. Kuchler and J. S. Zooneveld. Kluwer, Norwell, Massachusetts. x + 635 pp. U.S.$250.

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Wildflowers of the southern interior of British Columbia and adjacent parts of Washington, Idaho, and Montana. 1989. By Joan Burbridge. University of British Columbia Press, Vancouver. c400 pp., illus. Cloth $29.95; paper $19.95.

*__Wild rice in Canada.__ 1988. By S. G. Aiken, P. F. Lee, D. Punter, and J. M. Stewart. Agriculture Canada (distributed by NC Press, Toronto). 130 pp., illus. $18.95 in Canada; U.S.$22.75 elsewhere.

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Acidic deposition and forest soils. 1989. By D. Binkley, C. T. Driscoll, H. L. Allen, P. Schoeneberger, and D. McAvoy. Springer-Verlag, New York. viii + 149 pp., illus. U.S.$49.

Aquatic toxicology and environmental fate, volume 11. 1989. Edited by Glen W. Suter and Michael A. Lewis. ASTM, Philadelphia. 616 pp., illus. U.S.$74.

†**At the water's edge: nature study in lakes, streams, and ponds.** 1989. By Alan M. Dvancara. Wiley, Somerset, New Jersey. vii + 232 pp., illus. U.S.$10.95.

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Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; (613) 996-1755
Assistant to Editor: P. J. Narraway; **Copy Editor:** Joyce C. Cook
Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665
Book Review Editor: Dr. J. Wilson Eedy, R. R. 1, Moffat, Ontario L0P 1J0
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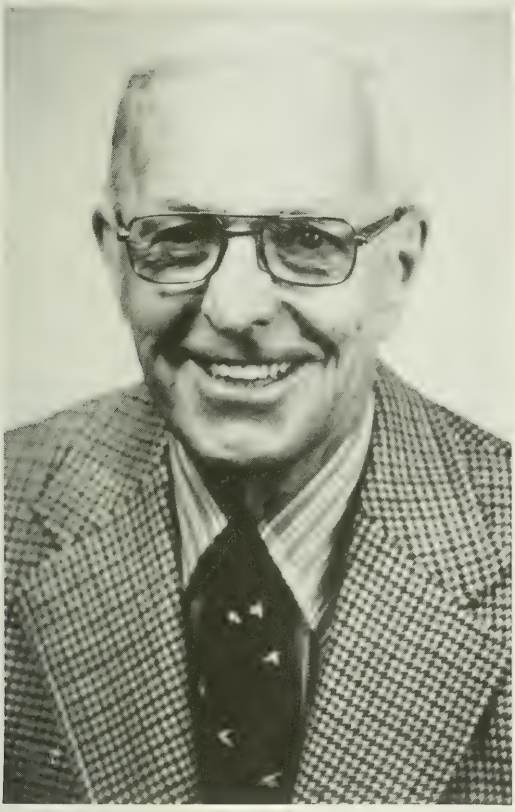
Cover: An adult female tundra Peregrine Falcon (*Falco peregrinus tundrius*) about to settle over eggs at an eyrie in the Keewatin District of the Northwest Territories. Photograph courtesy of Gordon S. Court. See article pages 255-272.

The Canadian Field-Naturalist

Volume 104, Number 2 April–June 1990

Peregrene Falcons in the 1980s

Dedication: Joseph Hickey



It is indeed a pleasure to dedicate this issue to Dr. Joseph Hickey. His dedication to the Peregrine Falcon and its conservation is unrivaled. In the late 1930s he organized a survey of the species throughout eastern North America so that the data could "be consulted by those who wish to study and evaluate subsequent population changes of this interesting species." I doubt if anyone reading the account in *The Auk* in the spring of 1942 realised how interesting and important these data would be.

The Madison Peregrine Conference of 1965 is too well known as a landmark for the environmental movement to need further comment. The proceedings, edited by Joe alone, have become a classic. His subsequent follow-up, with Dan Anderson, placed eggshell thinning in the peregrine and many other species on a firm statistical basis. Joe gave the opening address to the Sacramento Peregrine meeting, held twenty years after that at Madison. The comparison of the size of these two meetings says much for the growth of interest in environmental affairs. To mention just one statistic, the Sacramento meeting required four editors.

In his 1942 Auk article, Joe quotes that the ancient Persians deemed it necessary that a falconer "be good-tempered, pleasant spoken and of a cheerful and cherry countenance." Although not a falconer himself that description certainly applies to Joe Hickey.

DAVID B. PEAKALL

Prospects for the Peregrine Falcon, *Falco peregrinus*, in the Nineties

DAVID B. PEAKALL

Canadian Wildlife Service, National Wildlife Research Centre, Ottawa, Ontario K1A 0H3

Peakall, David B. 1990. Prospects for the Peregrine Falcon, *Falco peregrinus*, in the nineties. Canadian Field-Naturalist 104(2): 168–173.

The first continent-wide survey of Peregrine Falcons (*Falco peregrinus*) was taken in 1970 and was followed by additional surveys in 1975, 1980 and 1985. The results of those of the 1970s were previously published in *The Canadian Field-Naturalist* and the present issue summarizes data obtained in the 1980s. These studies combined provide the basis for assessment of the species' prospects in the nineties and for some suggestions on the emphasis for studies in the next decade. Ecological differences among three North American geographic races have contributed to their present differential success. *F. p. pealei* occurs and breeds along British Columbian and Alaskan coasts. *F. p. tundrius* breeds in the arctic and winters in Latin America. *F. p. anatum* occupied a broad band from interior Alaska south through western Canada and a narrow range in the central and eastern portions of the country. Of the three, *F. p. anatum* has been affected the most, and was extirpated in eastern Canada and the United States. *F. p. pealei* and *F. p. tundrius* seem secure enough that the costly five-year surveys may no longer be justified for them. *F. p. anatum* is still at risk and its former range has been the focus of re-introduction programs. The introduction of captive-bred stocks has met with more success in the United States than in Canada. The observation that many falcons are only seen for one season is disturbing. Allelic frequency and DNA fingerprinting would aid in determining the relative effect of different stocks used in the release programs. Levels of organochlorines are still a concern. Release sites should be carefully chosen and the analysis of abandoned eggs continued. Finally, the studies of residues in Latin America should take a broad approach to identify specific problems of pesticide usage.

Le premier inventaire pancontinental du Faucon pèlerin a été effectué en 1970 et suivi par d'autres inventaires en 1975, 1980 et 1985. Les résultats des inventaires des années 70 ont déjà été publiés dans un numéro du *Canadian Field-Naturalist* et le présent numéro résume les données obtenues dans les années 80. Regroupées, ces études fournissent un fondement pour l'évaluation des perspectives de l'espèce pour les années 90 et de quelques suggestions des points principaux à étudier pour la prochaine décennie. Les différences écologiques entre trois races géographiques nord-américaines ont contribué au succès présent. Le *F. p. pealei* se retrouve et se reproduit le long des côtes de la Colombie-Britannique et de l'Alaska. Le *F. p. tundrius* se reproduit dans l'Arctique et hiverne en Amérique latine. Le *F. p. anatum* occupe un large couloir, partant du sud de l'Alaska et traversant l'ouest du Canada, ainsi qu'une région plus étroite au centre et à l'est du pays. Parmi les trois races de faucons, le *F. p. anatum* a été le plus touché et était disparu dans l'est du Canada et aux États-Unis. La survie du *F. p. pealei* et du *F. p. tundrius* semble assurée et les inventaires coûteux de cinq ans pourraient ne plus être justifiés. Toutefois, le *F. p. anatum* est encore en danger et son ancien territoire a été le sujet de programmes d'introduction. L'introduction de Faucons élevés en captivité a eu plus de succès aux Etats-Unis qu'au Canada. Les observations que plusieurs faucons ne sont repérés que pour une saison de reproduction sont troublantes. La fréquence des gènes allomorphes et les études de traces d'ADN sont nécessaires pour déterminer l'effet relatif des différentes sources d'approvisionnement utilisées dans les programmes de lâchers. Les niveaux de contaminants organochlorés demeurent une inquiétude. Les zones de mise en liberté des faucons devraient être choisies avec soin et l'analyse d'organochlorés dans les oeufs abandonnés, poursuivie. Enfin, l'analyse des niveaux de contaminants organochlorés en Amérique latine devrait utiliser une approche plus vaste pour identifier les problèmes particuliers à cet endroit.

Key Words: Peregrine Falcon, *Falco peregrinus*, surveys, ecology, breeding, re-introductions, organochlorines.

This is the third issue of *The Canadian Field-Naturalist* to be devoted primarily to studies on the Peregrine Falcon (*Falco peregrinus*). I am both honoured and intimidated to follow in the foot-steps of Joe Hickey and Ian Newton in writing a preface to such an issue. Birds of prey have been considered good indicators of environmental health because they represent the terminal focus of food chains and thus are sensitive to any important change within the ecosystem. Certainly this has been the case for the organochlorine pesticides which bio-accumulated through the food chain exerting their greatest influence on the terminal predators. Nevertheless, we should be careful not to take the peregrine as the sole litmus paper of environmental quality. It is likely that the peregrine's choice of food (*see* Noble et al. this issue) is sufficiently catholic to buffer its population against many changes that may occur in its food-chain. The cliff-nesting peregrine is also likely to be largely unaffected by habitat change such as that caused by acid rain. Climate change may affect the peregrine in the Prairie Provinces; one might hypothesize that the Prairie Falcon

(*Falco mexicanus*) is likely to increase at the expense of the peregrine.

However, the question to be examined here is "What are the prospects for the peregrine in Canada in the 1990s? rather than "What does the peregrine tell us about the Canadian environment?"

The major factor in the decline of the peregrine has been the widespread use of organochlorine pesticides" As Cade (1968) expressed it: "Down through the centuries, not all the falcon trappers, egg collectors, war ministries concerned for their messenger pigeons, or misguided gunmen have been able to effect a significant reduction in the numbers of breeding falcons. But the simple laboratory trick of adding a few chlorine molecules to a hydrocarbon and the massive application of this unnatural class of chemicals to the environment can do what none of these other grosser, seemingly more harmful agents could do."

The ecological differences between the three sub-species that occur in Canada are so marked that it is necessary to consider each separately.

Falco peregrinus pealei is essentially resident along the coasts of British Columbia and Alaska. In the Queen Charlotte Islands, a major nesting area of this race, significant decrease in the population occurred from 1970 to 1975 and it has subsequently recovered (Munro and van Drimmelen 1988). While it is impossible to assign a definite cause, it can be pointed out that a significant proportion of eggs analysed from the late 1960s and early 1970s had levels of DDE above the critical range, (Peakall et al., this issue) and the residue levels of a small sample of eggs collected in 1986 are much lower, comfortably below critical levels. Kiff (1988), in his overview of the changes in status of the peregrine in North America, shows the range of *F. p. pealei* as the one area in which no significant decline occurred. Although other pressures can be listed, it appears that the future of *F. p. pealei* is dependent on the populations of its seabird prey along the Pacific coast of North America. Detailed studies of the population of the two chief prey species, Cassin's Auklet (*Ptychoramphus aeutica*) and Ancient Murrelet (*Synthliboramphus antiquum*) are not available, but apart from local declines of Cassin's Auklet around Langara Island, the populations appear to be in good shape (A. J. Gaston, personal communication).

In contrast, *F. p. tundrius* is highly migratory, breeding in the Arctic and wintering in Latin America. The population of *F. p. tundrius* declined markedly during the 1960s and the decline may have started as early as the 1950s. A decline of 65% between the late 1960s and 1985 was estimated for Alaska (Ambrose et al. 1988). Kiff (1988) calculated a population of 448 pairs in 1985 for the entire North American Arctic and Sub-arctic zone compared to an estimated historical population of 5000-8000 pairs. Comparison of the 1970, 1975 and 1980 surveys indicates that recovery started between 1975-1980. A further improvement was noted in most areas between 1980 and 1985. The levels of organochlorines in the eggs of *F. p. tundrius* have decreased and only a small proportion have levels above those considered critical (Peakall et al., this issue).

The data presented in this issue on the residue levels of potential prey species of Peregrine Falcons collected in Latin America shows generally low levels from Surinam and Costa Rica and higher levels from Peru and Ecuador (Fyfe et al., this issue). It is difficult to obtain data on the usage of pesticides in Latin America. Maltby (1980) estimated that the total usage of DDT in Latin America was 16 000 000 kg in 1978 and forecast a 25% decrease in the usage of this insecticide over the next decade. Four countries — Mexico, Brazil, Argentina and Columbia — accounted for 90% of the 1978 total. To put these figures in perspective, the total amount of DDT used in New Brunswick over the period 1952-1965 was 5 750 000 kg and maximum annual use was 600 000 kg. and the area of New Brunswick is a fifteenth of that of Columbia and less than one percent of Brazil.

F. p. anatum occupied a broad band from the interior of Alaska south through much of western Canada with rather narrower range across the central and eastern parts of the country. Its migrations are much more limited than those of *F. p. tundrius*. It was extirpated in the eastern half of Canada and in the eastern United States. The re-introduction program into eastern Canada has been detailed by Holroyd and Banasch elsewhere in this issue. Critical evaluation of the success of the re-introduction programs is essential.

The starting point of any evaluation of any aspect of the biology of the peregrine is the Sacramento meeting of November 1985 (Cade et al. 1988). In his thought-provoking summary to this conference Ian Nisbet (1988a) posed four "irreverent" questions: (1) What caused the population crashes?; (2) What is known about population dynamics of peregrines?; (3) What is being learned about the biology of the peregrine from captive breeding programs?; (4) Where have all the captive-reared birds gone?

These questions were also considered by the editors — Tom Cade, Jim Enderson, Carl Thelander and Clayton White — in the conclusion of the proceedings of the meeting. The first question they only considered briefly and since it is an issue that Ian Nisbet and I debated at Sacramento (Nisbet

1988b; Risebrough and Peakall 1988), I think we can leave this fascinating question with Ian's final words "the critical evidence — direct measures of exposure during the periods of decline — is lacking for nearly all areas." The more relevant questions are: "Do we know the levels of pollutants that are critical to the peregrine?" and "Are these levels still occurring in peregrines in the wild?" I would submit that we can answer the first question fairly well for most chemicals of concern on an individual basis. The data on which this statement is based are reviewed elsewhere (Peakall *et al.* this issue). Studies on raptors, however, of combinations of pollutants are few. The answer to the second question is that in some eggs the level of DDE is still uncomfortably close to that at which effects might be expected, especially in view of our lack of knowledge of the effect of combinations of chemicals. Also, we lack knowledge concerning the chronic — multi-generation — effects on raptors. Analysis of the Canadian sightings of released peregrines reveals the disconcerting fact that pairs only return for a short time, usually only one season (Holroyd and Banasch, this issue). Population dynamics data strongly suggests that adult mortality of the peregrine is normally low. It is possible that the levels of organochlorines increase sufficiently between the first and second years of breeding to cause problems. There are no good time series of eggs of individual females from eastern North America, but data from California indicate that equilibrium levels of organochlorine residues are reached in the second year (Kiff and Peakall, unpublished data). However, it is likely that the problems caused would be loss of eggs — due to breakage — or infertility rather than mortality of adults.

The editors of the Sacramento proceedings take a more positive approach to the second question than Nisbet, although, like, all researchers, they acknowledge the need for additional studies. In this context I would like to draw attention to the paper in this issue by Court and co-workers, and additional material published by this group elsewhere (Court et al. 1988, 1989). Apart from their importance as a contribution to our knowledge of the breeding biology of the peregrine, they raise an important question about the value of intensive — as opposed to extensive — surveys as the index of population in the Arctic where the harsh and variable climate can cause major annual changes in productivity. An evaluation of the need for extensive surveys is made later in this paper.

For the third question the editors again have a more positive attitude than Nisbet. The list of papers given by the editors is quite impressive. Personally, I have doubts on the value of studying many of the aspects of breeding biology that Nisbet lists in captive birds. On the other hand, I agree with Nisbet that it is important to identify the characteristics that lead to the survival of captive-bred birds in the ecological conditions into which we release them.

The last, and most critical, question posed by Nisbet is "Where have all the captive-reared bird gone?" It is this question that the Editors consider at greatest length. It is possible to come up with almost any answer when producing survivorship tables. From a Canadian perspective the data presented in Nisbet's only table, which compared the number of birds released with the number of breeding pairs found in 1985, is the most critical. In Canada, 588 released birds resulted in seven known breeding pairs, while for the eastern United States the 511 birds released resulted in 25 known breeing pairs. The pattern of the release figures for Canada (Fyfe 1988) is very similar to that for the eastern United States (compiled by the editors, Cade et al. 1988: p. 860). Thus, on the basis of the raw data, the Canadian program is only a quarter as successful as that in the eastern United States.

Reasons can be considered under two main, but not mutually exclusive, headings. The first is that the Canadian release program does produce less independent peregrines than the corresponding U.S. program and second that it only appears to be so. There are several possible reasons why the Canadian program is less successful. Perhaps the captive breeding techniques and mode of release are sufficiently different to lead to differential mortality, but this does not appear to be so. As far as release sites are concerned, the ratio of urban to rural is similar, although towers are not used in Canada. Limited residue level data (Gilroy and Barclay 1988; Peakall et al. this issue) do not indicate that organochlorine residues are higher in Canada than in the United States. The harsher Canadian winter may force longer migration patterns leading to increased mortality. The gene pool of the released birds is known to be different. This question is examined in more detail later.

There are also several factors which could make it appear that the Canadian program is less successful. Certainly it is possible that peregrines are breeding in Canada in areas remote from humans. The density of observers is much lower and access to possible breeding sites more difficult in Canada. As Joe said, nearly half a century ago (in formal terms, Hickey 1942), commenting on the fact that 67% of the 408 nesting sites were located in the United States, "this preponderance may simply reflect the intensity of field work in the central and eastern parts of the continent, rather than the geographic indication of the species' center of abundance." Happily both Joe and one of

the other major contributors to this survey — Walter Spofford — are still with us.

Nevertheless, the number of potential breeding sites in southern Canada may be less than that in the north-eastern United States; certainly the population in the Maritimes was never large. Emigration to the U.S. may be greater than immigration from the U.S. The data on banded birds are too limited to make a case one way or the other.

The gene pool used for captive breeding that provided birds for the release programs are markedly different. Temple (1988) presented data on the contributions of various sub-species to the gene pool of captive-reared peregrines that have been released in the eastern United States over the period 1975-1985. *F. p. tundrius* accounted for c45% and an equal contribution of c18% was made by *F. p. anatum* and the southern European *F. p. brookei.* Temple suggests the name "*Falco peregrinus cadei*" for this novel regional "sub-species". The Canadian release program used pure *F. p. anatum* stock although there was an effort to use as broadly based a stock as possible. Fyfe (1988) refers to twelve peregrine nestlings being collected from the wild in 1970 from eyries as far apart as the Mackenzie Valley and Labrador. Subsequently the gene pool was augmented by additional birds, mainly from the northern boreal forests. If we followed the lead of Stan Temple, the name of this "sub-species" should be "*Falco peregrinus fyfei.*"

These "names" are, of course, used most informally here; under the Internatioal Code of Zoological Nomenclature, formal scientific names cannot be applied to hybrids, nor are these stocks subspecies in a formal nomenclatural sense. *F. p. anatum* does not receive a new name on introduction.

Morizot (1988) has published preliminary account of the biochemical variability in peregrine populations. These data have been used to make estimates of the proportions of various populations in migrants trapped at Assateague Island, Virginia and Padre Island, Texas. The findings suggest that the percentage of North Slope Alaskan birds in Virginia and of Greenland birds in Texas are higher than is suggested by banding data. Although the author mentions samples from the captive breeding colonies at Ithaca, New York and Wainwright, Alberta these data do not appear in tabulated data nor are they discussed in the text. It would be fascinating to know allele frequencies for "*cadei*" and "*fyfei*". Detailed DNA studies of released birds would also be informative, but regrettably these techniques were not available when the releases program began fifteen years ago. Even at this stage it would be useful to have information on the allele frequencies of birds released in Canada and United States. In view of the marked differences in the gene pool used it should certainly be possible to determine the amount of interaction between the birds released in the two countries. A comparison between the success of the two stocks of such different genetic composition — one from a single sub-species of a population that had passed through a relatively narrow neck and the other that was broadly based involving several sub-species — released in comparatively similar areas might well have considerable theoretical interest and practical importance. One would suppose that variability in "*fyfei*" would be markedly lower than in "*cadei*". While such restriction are viewed with some alarm, on the grounds that decreased variability gives the species a decreased chance of survival if faced with new conditions, it should be pointed out that the Elephant Seal (*Mirounga angustirostris*) passed through a narrow neck and since then the population has increased greatly despite its very low genetic diversity.

Before World War II there were only a few cases recorded of peregrines nesting in big cities, most notably the famous Sun-Life pair in Montreal. Thus, the urbanization of the peregrine in eastern North America represents a major change in its ecology. One unanswered and indeed unanswerable question is whether this phenomenon would have occurred naturally as clusters of high buildings became the norm. Essentially there were no peregrines in eastern North America during the 1950s and 1960s, and in other areas of the world the numbers were depressed so that colonization of new habitat would be unlikely. As Cade and Bird make clear in their article it is not merely that urban sites were used as release sites as there are instances of rural released birds entering the city to breed, and peregrines have colonized several cities in which no releases were made. They hypothesize that captive-raised birds are less afraid of humans and have more knowledge of artificial structures. If this is correct it will be interesting to see what future generations of peregrines do, although it will be impossible to know with any certainty what has been the role of such experience.

The saga of the colonization of cities by the peregrine will be followed with great interest. At the moment it is not possible to say what is the true breeding successs of these urban peregrines. There is great interest in the fate of the birds, many are fed artificially, and many fledglings are rescued. Most of the interest is positive, but the pigeon fanciers have strong antagonism to the peregrine. Only when the interest in the species dies down will we really be able to see how well the peregrine is adapting to that most unnatural of all environments, the core of the big city.

Another problem that needs a decision is how much and what type of census work should be carried out on the peregrine. In 1970, on the heels of the discovery that the peregrine population in eastern North America was gone and that the Alaskan populations, like many others throughout the northern temperate zone, were greatly reduced, the first North American peregrine survey of breeding pairs was organized. There can be no doubt about the need for this survey, it was essential to document the status of the species. It confirmed the suspicion that the peregrine was indeed in poor shape over wide areas of the Arctic. The 1975 survey confirmed this although there were signs that the downward movement of the population had been arrested. The 1980 and 1985 surveys, both published in this issue of *The Canadian Field-Naturalist*, confirm the findings from elsewhere (documented at the Sacramento meeting, Cade et al. 1988) that the status of the species has improved considerably. As I write, the plans for the 1990 survey are being implemented. It is hard to come up with a definite figure for the cost of this survey but it is in the tens of thousands of dollars. Certainly the time has come to examine the policy of five-year surveys. The amount of time and effort that is available for conservation projects is limited and the question "Is this the best use of money and human resources?" must be asked.

Court et al. in this issue puts forward the idea that annual intensive studies are more cost effective than extensive surveys. The weakness of extensive surveys is that the results are highly dependent on the weather conditions of that particular year. While annual intensive studies get round this point, the extrapolation to the entire region from a few data points causes a good deal of uncertainty in the data. Further, although Court and co-workers argue that the data can be collected on only three visits, the cost of an annual program to obtain this data may well equal the five-year broad survey.

Another censusing technique is based on sighting and trapping data on migration. Looking at the data from Assateague Island, Virginia, we see that 63 peregrines were sighted in 1970, 145 in 1975, 369 in 1980 and 483 in 1985 compared to an annual figure of 475 for the period 1939-1947 (Ward et al. 1988). In this type of data there are problems of re-sighting and, conversely, of birds not sighted and, with the exception of trapping of banded birds or sightings of color bands or dye, we know nothing of the origin of these birds. Nevertheless, the annual sightings from Assateague certainly reflect the population changes known from the five-year surveys.

The migration pattern of the peregrine is highly complex. Yates et al. (1988) have plotted the recoveries of Canadian banded peregrines. Most of those banded in the Northwest Territories migrate over the Caribbean to South America, whereas some birds from the Yukon Territories, and most of the birds from Keewatin and northern Quebec, migrate via the east coast of the United States. The remainder of the birds from these areas migrate due south to the Gulf of Mexico. The bulk of the recoveries of birds banded in Alaska occurred at the Gulf of Mexico, although there is one recovery from the east coast.

Following fairly closely on the heels of the publication of the Sacramento Conference, one has to justify another volume on the peregrine. First, this issue of *The Canadian Field-Naturalist* has provided a vehicle for the publication of the 3rd and 4th major surveys of the peregrine. From a Canadian perspective it provides the data base available on the organochlorine residues in both the peregrine and its prey and a comparison to other raptors. The data on the residues in peregrine prey from Latin America provides the first published survey of this type. The details of the Canadian release program had not been previously published and the review, from both sides of the longest undefended border in the world, of the rise of the urban peregrine is an important contribution. Based on all this information let me offer the following conclusions and recommendations:

1). The health of the *F. p. pealei* and *F. p. tundrius* populations in Canada, as we enter the 1990s, is good. Further extensive surveys in the arctic such as those undertaken in 1970, 1975, 1980 and 1985 do not appear to be justified unless they are part of a broader program undertaken to study the biology of the north.

2). The status of *F. p. anatum* in eastern Canada remains a source of concern. So far the release program has been apparently less successful than its American counterpart. A survey of eastern Canada, south of the tree-line, would be useful to determine if, in fact, the population is larger than known at present. Studies on frequency of alleles and fingerprinting of the DNA of peregrines in eastern North America would be valuable to determine the proportion of birds coming from the U.S. and Canadian release programs.

3). The levels of organochlorines in peregrine eggs are still uncomfortably close to critical levels even in eastern Canada where it can be assumed that the birds do not migrate to Latin America although their prey may do so. The finding that many falcons are only seen at breeding sites for one summer is disturbing. While there is no evidence that pesticides are involved, it is possible that there is enough of an increase between the first and second years to cause failure. Care should be taken over the selection of release sites, especially for the large releases (20 to 30 young per year per area) proposed by Holroyd and Banasch. For each such area studies should be carried on the initial releases to determine the

principal prey selected and analysis for organochlorines should be carried out on these species. Only those areas, in which it is demonstrated that the levels of organochlorines in prey are below critical levels, should be used for mass releases. Most shorebirds in the Bay of Fundy have been shown to have low organochlorine residue levels, whereas residues levels are still high in gulls in the Great Lakes and along the St. Lawrence. No deliberate collection of peregrine eggs is proposed, but the analysis of levels in abandoned eggs in the east should be continued. Current evidence suggests that the levels determined in this manner are typical of the population.

4). Additional studies on the levels of organochlorines in wildlife in Latin America would be of value because of the very limited data now available. However, this should not be geared specifically towards peregrine prey, but rather take a broader approach with the idea of identifying specific problems in Latin America.

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The 1980 North American Peregrine Falcon, *Falco peregrinus*, Survey

CLAYTON M. WHITE[1], RICHARD W. FYFE[2], and DAVID B. LEMON[3]

[1]Zoology Department, Brigham Young University, Provo, Utah 84602.
[2]P.O. Box 3263, Ft. Saskatchewan, Alberta T8L 2T2.
[3]General Delivery, Topsail, Conception Bay South, Newfoundland A0A 3Y0.

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Most areas of North America were surveyed for nesting of the Peregrine Falcon (*Falco peregrinus*) in 1980. Specific areas not adequately surveyed include the Aleutian Islands, southeast Alaska, Greenland, Labrador and Mexico. Compared to the 1975 North American surveys, many regional populations in 1980 had higher numbers of occupied sites and higher site productivity. There appeared to be a complete population recovery of Peregrine Falcons along portions of the Yukon River. Areas adjacent to the Yukon River, however, have remained stable at low levels or have declined further compared to previous survey results. The Mackenzie River Valley population appears to have remained stable whereas the population on the Mackenzie River delta has continued to decline. The arctic populations showed a trend toward stability in some areas whereas other areas had slight increases or declines since 1975. The Pacific maritime populations have remained stable since 1975 and population levels there are either near capacity or have already recovered to former numbers. No Peregrine Falcons were observed in southern Alberta, Saskatchewan, Manitoba, Ontario or Nova Scotia. Southern Quebec and northern Alberta had a total of 11 pairs of nesting Peregrine Falcons. The eastern United States had three nesting pairs in 1980 compared to no known pairs in 1975. The western United States and Mexico had at least 185 occupied sites compared to 62 in 1975. The increase observed in the western United States and Mexico is primarily a result of more search effort. The North American Peregrine Falcon population has stabilized since the population decline was identified in the 1960s. However, population increases or declines are continuing on a local level.

En 1980, on a étudié la nidification du Faucon pèlerin (*Falco peregrinus*) dans la plupart des régions de l'Amérique du Nord. Certaines régions n'ont pas été étudiées suffisamment; ce sont les îles Aléoutiennes, le sud-est de l'Alaska, le Groenland, le Labrador et le Mexique. Comparativement aux enquêtes nord-américaines de 1975, les données démontrent qu'en 1980, plusieurs populations régionales occupaient un plus grand nombre de sites et avaient un taux de reproduction plus élevé. Il semble y avoir eu un rétablissement complet de la population de Faucons pèlerins le long de certaines parties du fleuve Yukon. Les données des régions adjacentes au fleuve Yukon sont toutefois demeurées stables, à des niveaux bas, ou ont encore décliné en comparaison avec les résultats du relevé précédent. La population de la vallée du fleuve Mackenzie semble être demeurée stable tandis que la population du delta du fleuve Mackenzie a continué de décliner. Les populations arctiques démontrent une tendance à la stabilité dans certaines régions tandis que dans d'autres, elles se sont accrues ou elles ont diminué depuis 1975. Les populations de la côte du Pacifique sont demeurées stables de puis 1975 et les niveaux des populations à cet endroit sont presque rétablis ou ils ont déjà atteint les nombres précédents. Aucun Faucon pèlerin n'a été observé au sud de l'Alberta, en Saskatchewan, au Manitoba, en Ontario ou en Nouvelle-Écosse. Au sud du Québec et au nord de l'Alberta, on a relevé un total de 11 couples de Faucons pèlerins nicheurs. L'est des États-Unis comptait trois couples nicheurs en 1980 tandis qu'en 1975 on n'en avait relevé aucun. L'ouest des États-Unis et le Mexique ont au moins 185 sites habités comparativement à 62 en 1975. L'augmentation observée dans l'ouest des États-Unis résulte principalement de recherches plus poussées. La population nord-américaine de Faucons pèlerins s'est stabilisée depuis que son déclin a été reconnu au cours des années 60. Des augmentations ou des diminutions de populations continuent toutefois à l'échelle régionale.

Key Words: Peregrine Falcon, *Falco peregrinus*, Survey, North America.

The Madison Peregrine Conference in 1965 first documented the severity of the Peregrine Falcon (*Falco peregrinus*) population decline in North America (Hickey 1969). This resulted in an effort to determine the extent of the population decline. In 1969, a raptor conference held at Cornell University reviewed the most recent field data on peregrine populations and recommended that a North American survey of peregrine eyries be conducted every five years beginning in 1970. The results of the 1970 (Cade and Fyfe 1970) and 1975 (Fyfe et al. 1976) surveys indicated that migratory peregrine populations continued to decline throughout most of their northern and interior ranges. The relatively sedentary population of Pacific marine peregrines remained stable.

The surveys reported herein represent a considerable increase in effort to determine the abundance, distribution and reproductive success of the North American peregrine population compared to the 1970 and 1975 surveys. The increased effort reflects an overall public

awareness and support of peregrine related projects. This has resulted in peregrine conservation and management projects receiving funding from government and non-government agencies, and the support of volunteers.

This paper is a brief review of the 1980 surveys and will provide wildlife researchers and managers with essential information on the North American peregrine population in 1980. This survey is intended to complement the surveys reported in Cade and Fyfe (1970) and Fyfe et al. (1976). Cade et al. (1988) provide a thorough review of North American Peregrine Falcon populations, including results from this study and more recent data.

Methods

The 1980 survey in Canada was coordinated by the Canadian Wildlife Service who provided guidelines for collecting and recording data. The same guidelines were provided for United States participants. The peregrine surveys were conducted using a variety of methods including automobile, boat, helicopter and fixed-wing aircraft. Ground checks of nest sites were made when conditions allowed. Nest sites were ground checked using noise makers to cause the birds to fly from the site, climbing to sites or observing sites with binoculars or spotting scopes.

In this paper, a nest site is defined as any location where peregrines have been observed and a nesting attempt has been documented. An occupied site is defined as a site occupied by a pair of adults or a single adult.

Non-essential data from individual surveys has been omitted to keep the focus of the paper on the North American peregrine population. However, the names and addresses of the contributors for each survey are provided in the acknowledgments for reference purposes.

Due to the length of time between the 1980 surveys and the publication of these results, outdated material has been omitted and previously published material has been either omitted or cited appropriately. The original manuscript (80 pages of text plus 40 tables) containing detailed information is on file with the first two authors and the U.S. Fish and Wildlife Service, Office of Endangered Species, Washington, D.C. 20240. Specific data can be obtained from that manuscript. The literature cited in that manuscript was comprehensive.

Results and Discussion

The results of the peregrine surveys conducted in 1980 are presented in Table 1. The North American overview of the 1980 survey results that follows is based on five regions; the Arctic tundra, the boreal forest north of 60°N latitude, the boreal forest south of 60°N latitude, the Pacific northwest, and the continental United States (excluding Alaska) and Mexico.

For a thorough overview of the peregrine status in North America, which comprises the survey efforts conducted prior to 1980, the 1980 surveys reported in this paper, and more recent survey results, the reader should refer to Kiff (1988).

The Arctic Tundra Region

This region comprises the Canadian Arctic, Greenland and the arctic portions of Alaska.

The number of occupied peregrine sites in the Canadian Arctic has recently increased as a result of numerous raptor surveys associated with environmental impact assessment projects in 1976 and 1977. These recent surveys located approximately 100 new sites which double the total number of known sites for the interior barrens. Calef and Heard (1979) presented results of two surveys that indicated high reproduction and site occupancy rates in the Canadian Arctic. In 1980, concerted efforts were made to survey the recently located sites, in particular the new sites in the Wager Bay area. As a result, the 1980 surveys of the arctic barrens and coastal areas were more through compared to previous surveys in these areas. Therefore the surveys presented in this paper are considered to be more representative of the arctic peregrine population than estimates determined from previous surveys.

Most of the 1980 surveys in the Canadian Arctic were adversely affected by poor weather conditions throughout the summer following a later than usual arrival of spring. There were many surveys delayed or aborted due to weather. However, survey crews were confident of the reliability of the results they managed to collect and only presented those results. For example, during the survey of the Wager Bay area, 30 of the 37 known sites were visited but at only 21 of the sites were the survey results satisfactory. Consequently, only 21 sites are included in the survey.

The peregrine populations on the central coast, interior barrens and Ungava have remained relatively stable with 40-45% site occupancy. The Thelon River results indicate a slight population increase from previous surveys.

Local peregrine population declines in the arctic have not entirely stopped. On the Yukon North Slope west of the Mackenzie River delta only two single adult peregrines were observed at 16 known sites. On Baffin Island, peregrines were not present at any of six sites. The 1980 Wager Bay survey also indicated a population decline whereas earlier studies in the same area indicated the population was stable with high nest productivity (Calef and Heard 1979). The 1980 Wager Bay survey

TABLE 1. Results of the 1980 North American Peregrine Falcon Surveys.

Survey Region	Total Known Sites	Sites Checked	Sites Occupied (pairs)	Percent Occupancy	Pairs with Young/Pairs Checked	Total Number Young	Young per Pair	Young per Successful Pair
West Greenland	28	25	16(14)	64	12/14	36	2.4	3.0
Ungava Bay, Quebec/NWT	28	21	10(10)	48	10/10	27	2.7	2.7
South Baffin Island, NWT	8	6	1(0)	14	1/1	3	3.0	3.0
Rankin Inlet, NWT	11	9	8(8)	89	7/8	20	2.9	3.3
Wager Bay, NWT	37	24	9(4)	38	4/4	10	2.5	2.5
Thelon River and Interior Barrens, NWT	30	28	13(9)	46	5/5	13	2.6	2.6
Anderson and Horton Rivers, NWT	23	23	8(6)	35	2/2	6	3.0	3.0
Central Arctic Coast, NWT	24	23	9(5)	39	4/5	14	2.2	2.6
Victoria and Banks Islands, NWT	26	26	15(7)	58	n/a	n/a	n/a	n/a
Yukon North Coast	16	16	2(0)	13	n/a	0	0.0	0.0
Central and Eastern Arctic Slope, Alaska	13	13	3(3)	23	1/2	2	1.0	2.0
Colville River, Alaska	51	51	23(21)	45	12/21	29	1.4	2.4
Mackenzie River Valley, NWT	48	43	20(15)	47	6/8	12	1.5	2.0
Porcupine River, Yukon	24	22	16(13)	73	9/13	15	1.1	2.0
Peel River, Yukon	28	26	18(12)	69	0/6	0	0.0	0.0
Yukon River, Yukon	14	14	12(10)	86	6/10	13	1.3	2.1
Alsek River, Yukon	3	3	0(0)	0	n/a	0	0.0	0.0
Upper Yukon River, Alaska	24	24	20(17)	80	16/17	44	2.6	2.8
Charley River, Alaska	7	7	5(3)	71	2/3	3	1.0	1.5
Porcupine River, Alaska	12	12	10(9)	83	6/9	13	1.4	2.2
Middle Yukon River, Alaska	10	10	6(6)	60	4/6	11	1.8	2.8
Lower Yukon River, Alaska	48	48	39(32)	81	27/32	69	2.2	2.6
Southwest Alaska	5	5	4(3)	60	3/3	8	1.6	2.7
Tanana River, Alaska	22	20	4(4)	20	2/4	5	1.3	2.5
Saskatchewan	0	n/a	0(0)	0	0/0	0	0.0	0.0
Nova Scotia	6	5	0(0)	0	0/0	0	0.0	0.0
Southern Quebec	2	2	1(1)	50	1/1	2	2.0	2.0
Ontario	26	26	0(0)	0	0/0	0	0.0	0.0
Lower Churchill River, Manitoba	0	n/a	0(0)	0	0/0	0	0.0	0.0
Alberta, north of 58°N	18	18	9(9)	50	6/9	19	2.1	3.2
Alberta, south of 58°N	53	53	0(0)	0	0/0	0	0.0	0.0
Eastern United States	181	152	3(3)	2	3/3	6	2.0	2.0

TABLE 1. *(Concluded)*

Survey Region	Total Known Sites	Sites Checked	Sites Occupied (pairs)	Percent Occupancy	Pairs with Young/Pairs Checked	Total Number Young	Young per Pair	Young per Successful Pair
Upper Mississippi River, Lake Superior (north shore) and Border Lakes	30	30	0(0)	0	0/0	0	0.0	0.0
Washington	13	13	4(3)	37	2/3	4	1.3	2.0
Oregon	70[1]	39	1(1)	3	0/0	0	0.0	0.0
Montana	11	11	0(0)	0	0/0	0	0.0	0.0
Idaho	17	9	1(0)	11	0/0	0	0.0	0.0
Wyoming	18	18	0	0	0/0	0	0.0	0.0
Utah	40	0	7(7)	18	3/7	5	0.7	2.5
Nevada	5	5	2(0)	40	0/0	0	0.0	0.0
Colorado	36	30	13(10)	43	5/7	16	2.3	3.3
Arizona	26	26	17(14)	66	11/14	22	1.6	2.2
New Mexico	27	24	16(15)	67	9/15	19	1.5	2.1
California	146	146	43(39)	30	24/36	67	1.7	2.5
Texas and northeast New Mexico	No surveys conducted in 1980[2].							
Baja and Gulf of California, Mexico	97	35	29(26)	83	12/26	21	n/a	1.8
Aleutian Islands — Alaska Peninsula	127[3]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Coastal and Inland Regions, southeast Alaska	23	23	19(15)	83	15/15	17	1.1	n/a
Outer Coast, southeast Alaska	n/a	n/a	36(15)	n/a	1/—	2	2.0	2.0
Vancouver and Gulf Islands, British Columbia	9	9	3(2)	33	n/a	n/a	n/a	n/a
Langara Island, British Columbia	6	6	6(6)	100	6/6	13	2.2	2.2
Queen Charlotte Islands, British Columbia	122	109	71(58)	65	11/13	27	2.1	2.5

[1]Source Walton et al. (1988).
[2]For a review of Texas and Northern Mexico see Hunt et al. (1988).
[3]Minimum number of sites.

indicated a decrease in site occupancy from approximately 59% to 38% since the 1976-77 surveys conducted by Calef and Heard (1979).

The west Greenland peregrine population appears to have remained stable since 1972 with an annual site occupancy rate of approximately 60%. The number of known sites in west Greenland has increased by approximately 60% since 1972.

In the Alaskan Arctic, only 29% of the historical sites surveyed on the Colville River were productive but when new sites in addition to historical sites are considered, approximately 57% of all sites produced young. Other areas in the Arctic had similar site occupancy rates and survey results suggest the peregrine population has stabilized.

More recent peregrine population estimates and population trends for this region can be found in Mattox and Seegar (1988) for Greenland; Falk and Moller (1988) for south Greenland; Bird and Weaver (1988) for Ungava Bay, Quebec; Bromley (1988) for Kitikmeot, Baffin and Keewatin, Northwest Territories; Mossop (1988) for the Yukon; Ambrose et al. (1988) for Alaska.

The Boreal Forest Region North of 60° N

This region comprises areas of central and northern Alaska, the Yukon and Northwest Territories below treeline and north of 60°N latitude.

The results of the 1980 peregrine surveys in this region indicated the beginning of a population recovery when compared to previous surveys. The most extensive recovery was documented along the Yukon River. The Yukon Territory populations recovered dramatically from apparently low levels in 1977. This recovery was aided by an immigration of peregrines moving up the Yukon River from Alaska as determined by band recoveries. Forty-eight peregrine nest sites have been located along the lower Yukon River in Alaska since 1977. This represented approximately 30% of the total known sites in Alaska. The peregrine population along the lower Yukon River, Alaska, was very productive and accounted for 36% of the young produced in Alaska in 1980. In contrast, the Tanana River peregrine population in Alaska had only a 20% site occupancy rate. A new Peregrine nest site was located near the effluent of the Copper River, an area where peregrines were not previously known to nest.

Peregrine populations along the Porcupine and Mackenzie Rivers either showed an increase in site occupancy rate or remained stable. Recent data from the Peel River and Campbell Hills (Mackenzie River delta) indicated a severe population decline possibility as a result of reproductive failure and decreased site occupancy rate.

More recent peregrine population estimates and population trends for this region can be found in Bromley and Matthews (1988) for the Mackenzie River Valley, Northwest Territories; Mossop (1988) for the Yukon; Ambrose et al. (1988) for Alaska.

The Boreal Forest Region South of 60° N

This region comprises areas of mainland Canada south of 60°N latitude excluding Pacific coastal areas.

The 1980 surveys conducted in the boreal forest regions south of 60°N were the most complete to date, although historical sites in Labrador and New Brunswick were not surveyed. Cade and Fyfe (1970) and Fyfe et al. (1976) reported a near complete disappearance of peregrines for this region in 1970 and 1975. The 1980 surveys investigated 141 of the 150 known sites in this region in addition to many areas of suitable habitat in Quebec, Saskatchewan and Manitoba. No peregrines were observed in southern Alberta, Saskatchewan, Ontario, Manitoba or Nova Scotia.

Eleven sites were active in 1980 in northern Alberta and southern Quebec. Another historical site in southern Quebec was occupied in 1979. Eight of the peregrines observed at these sites in 1979 and 1980 were raised in captivity and released from the Cornell University and Camp Wainwright captive breeding facilities. Many of the other peregrines occupying these sites were also banded but their origin could not be determined. One peregrine occupying a site was released in 1977 in Edmonton, Alberta.

The Pacific Northwest Maritime Region

This region comprises southeast Alaska, the Aleutian Islands and the Queen Charlotte and Gulf Islands off the coast of British Columbia.

Although the surveys conducted in the Aleutian Islands area were incomplete, the results suggested that the number of nesting peregrines there is large and productivity appears healthy. At least 33 nest sites were located in southeast Alaska between 1978 and 1981 on coastal islands and on the mainland. In addition, 36 coastal cliffs on outer islands were occupied. Eight sites in southeast Alaska were located in tree cavities and one appeared to be in an *Accipiter* sp. nest. The locations of the tree cavity nesting peregrines indicates a 300–400 km northward extension of tree nesting peregrines that were reported in British Columbia by Campbell et al. (1977). There is a possibility that a large population of tree nesting peregrines exists in southeast Alaska.

The peregrine population on the coast of British Columbia appeared to remain stable. The lack of obvious population fluctuations in this area indicated that the nesting density of peregrines

may be near its maximum. Survey results from Langara Island have remained consistent. The remaining areas of the Queen Charlotte Islands surveyed indicated that a definite population increase is occurring. The site occupancy in the Queen Charlotte Islands was approximately 67% and in the Gulf Islands, approximately 56%.

More recent peregrine population estimates and population trends for this region can be found in Munro and van Drimmelen (1988) for British Columbia; Ambrose et al. (1988) for Alaska.

The United States (excluding Alaska) and Mexico Region

This region comprises the continental United States (excluding Alaska) and northwest portions of Mexico.

The peregrine population in the continental United States east of the Mississippi River consisted of three nest sites in 1980. Two of the three pairs consisted of captive bred and released birds nesting on made-made towers in New Jersey and the third pair was of undetermined origin in coastal Maine.

The peregrine population in the continental United States west of the Mississippi River consisted of 145 pairs and at least 185 occupied sites. This compares to 62 pairs in 1975. The apparent increase in 1980 was thought to reflect an increase in survey effort rather than being indicative of a population recovery. Many of the newly discovered occupied sites were located in California, Arizona, New Mexico and Mexico. The 11 new occupied sites located in California and the greater number of occupied sites in Mexico were clearly the results of increased survey effort. The increase in numbers in Baja and the Gulf of California area may have represented a true population recovery in addition to increased survey efforts. The peregrine populations in Colorado continued to show signs of decline even though two new occupied sites were located.

More recent peregrine population estimates and population trends for this region can be found in Enderson et al. (1988) for Colorado; Ellis (1988) for Arizona; Walton et al. (1988) for California, Oregon, Washington and Nevada; Porter et al. (1988) for Baja California and the Gulf of California, Mexico; Hunt et al. (1988) for Texas and Northern Mexico.

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Principal Contributors of Survey Results:

West Greenland: W. G. Mattox, Ohio Department of Natural Resources, Columbus, Ohio 43229; W. A. Burnham, F. P. Ward, W. S. Seegar. **Ungava Bay, Quebec/NWT:** D. M. Bird, Macdonald Raptor Research Centre, Ste. Anne de Bellevue, Quebec H9X 1C0; J. D. Weaver. **South Baffin Island, NWT:** G. Court and P. Trefry, Canadian Wildlife Service, Edmonton, Alberta T6B 2X3. **Rankin Inlet, NWT:** G. L. Erickson, Alberta Fish and Wildlife Division, Edmonton, Alberta T6H 4P2; C. Gates. **Wager Bay, NWT:** G. L. Erickson, Alberta Fish and Wildlife Division, Edmonton, Alberta T6H 4P2; D. Jacobs. **Thelon River and Interior Barrens, NWT:** L. Dickson and V. Stringer, Canadian Wildlife Service, Edmonton, Alberta T6B 2X3; G. Erickson, R. Bullion, J. and J. Faulkner, R. Moore, R. Turner. **Anderson and Horton Rivers, NWT:** T. Barry, Canadian Wildlife Service, Edmonton, Alberta T6B 2X3. **Central Arctic Coast, NWT:** H. Armbruster, Canadian Wildlife Service, Edmonton, Alberta T6B 2X3; K. Lloyd. **Victoria and Banks Islands, NWT:** G. Alliston, LGL Ltd., Toronto, Ontario M4R 1A1; L. Dickson, U. Banasch. **Yukon North Coast:** D. Mossop and R. Hayes, Yukon Wildlife Branch, Whitehorse, Yukon Y1A 2C6. **Central and Eastern Arctic Slope, Alaska:** D. Roseneau, P. Bente and A. Springer, LGL Alaska Research Associates, Fairbanks, Alaska 99708. **Colville River, Alaska:** R. Ambrose, U.S. Fish and Wildlife Service, Anchorage, Alaska 99503. **Mackenzie River Valley, NWT:** L. Dickson, U. Banasch and G. Court, Canadian Wildlife Service, Edmonton, Alberta T6B 2X3. **Porcupine River, Peel River, Yukon River and Alsek River, Yukon:** D. Mossop and R. Hayes, Yukon Wildlife Branch, Whitehorse, Yukon Y1A 2C6. **Upper Yukon River, Alaska:** R. Ambrose, U.S. Fish and Wildlife Service, Anchorage, Alaska 99503. **Charley River, Alaska:** R. Ambrose, U.S. Fish and Wildlife Service, Anchorage, Alaska 99503. **Porcupine River, Alaska:** R. Ritchie and J. Curatolo, Alaska Biological Research, Fairbanks, Alaska 99708. **Middle Yukon River and Lower Yukon River, Alaska:** A. Springer, P. Bente and D. Roseneau, LGL Alaska Research Associates Ltd., Fairbanks, Alaska 99708. **Southwest Alaska:** P. Mindell, Harvard University, Cambridge, Massachusetts 02138; R. Dotson. **Tanana River, Alaska:** D. Roseneau, P. Bente and A. Springer, LGL Alaska Research Associates Ltd., Fairbanks, Alaska 99708. **Saskatchewan:** S. Barber, M. Hlady and J. Kinnear, Tourism and Renewable Resources, Regina, Saskatchewan S4S 5W6; R. Rafuse. **Nova**

Scotia: A. Smith, Canadian Wildlife Service, Sackville, New Brunswick; P. Barkhouse. **Southern Quebec:** D. Bird, Macdonald Raptor Research Centre, Ste. Anne de Bellevue, Quebec H9X 1C0; M. Bureau, N. David, M. Lepage. **Ontario:** S. Bradley, 95 Arlington Avenue, Toronto, Ontario M6G 3C2. **Lower Churchill River, Manitoba:** W. Koonz, Department of Natural Resources, Winnipeg, Manitoba R3H 0W9; W. Anderson (deceased). **Alberta north of 58°N:** L. Johnston-Beaver, General Delivery, Roseneath, Ontario K0K 2X0. **Alberta south of 58°N:** Alberta Fish and Wildlife Division, Calgary, Alberta T2H 0G1, O. Pall (deceased). **Eastern United States:** P. Nickerson, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts 02158. **Upper Misissippi River, Lake Superior (north shore) and Border Lakes:** P. Redig, College of Veterinary Medicine, University of Minnesota, St. Paul, Minnesota 55108. **Washington:** C. Anderson, Kirkland, Washington 98033; F. Dobler, S. Herman. **Oregon:** C. Henney, U.S. Fish and Wildlife Service, Corvallis, Oregon 97333. **Montana:** J. Summer, Arlee, Montana 59821. **Idaho:** R. Howard, U.S. Fish and Wildlife Service, Boise, Idaho 83705; M. Nelson. **Wyoming:** R. Oakleaf, Wyoming Game and Fish Department, Lander, Wyoming; M. Jenkins. **Utah:** A. Heggen and P. Wagner, Utah Division of Wildlife Resources, Salt Lake City, Utah 84116. **Nevada:** G. Herron, Nevada Department of Wildlife, Reno, Nevada 89520. **Colorado:** G. Craig, Colorado Division of Wildlife, Fort Collins, Colorado 80526; J. Enderson. **Arizona:** D. Ellis, Patuxent Wildlife Research Centre, Laural, Maryland 20708: J. Fackler. **New Mexico:** J. Hubbard, New Mexico Department of Game and Fish, Santa Fe, New Mexico 87503. **California:** D. Harlow, U.S. Fish and Wildlife Service, Sacramento, California; B. J. Walton, C. G. Thelander, D. Boyce, G. Monk, M. Kirven, T. Scott, L. Kiff. **Texas and northeast New Mexico:** W. Hunt, Chihuahuan Desert Research Institute, Alpine, Texas 79830. **Baja and Gulf of California, Mexico:** R. Porter and M. Jenkins, U.S. Fish and Wildlife Service, Denver Federal Center, Denver, Colorado 80225; M. Kirven. **Aleutian Islands-Alaska Peninsula:** B. Day, Institute of Marine Sciences, University of Alaska, Fairbanks, Alaska 99775; P. Heglund, B. Reiwing, T. Early, E. Baily, D. Nysewander. **Coastal and Inland Regions, Southeast Alaska:** D. Van Horn, Malheur National Forest, John Day, Oregon 97845. **Outer Coast, southeast Alaska:** P. Schemph, U.S. Fish and Wildlife Service, Juneau, Alaska 99802. **Vancouver and Gulf Islands, British Columbia:** R. Davis, C. Elliot and G. Smith, B.C. Fish and Wildlife Branch, Nanaimo, British Columbia. **Langara Island, British Columbia:** R. W. Nelson, Camrose, Alberta T4V 2W6. **Queen Charlotte Islands, British Columbia:** K. Hodson and B. van Drimmelen, B.C. Fish and Wildlife Branch, Smithers, British Columbia V0J 2N0.

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The 1985-1986 Canadian Peregrine Falcon, *Falco peregrinus*, Survey

JULIA E. MURPHY

Canadian Wildlife Service, Ottawa, Ontario K1A 0H3
Present address: Faculty of Environmental Studies, York University, North York, Ontario M3J 1P3

Murphy, Julia E. 1990. The 1985-1986 Canadian Peregrine Falcon, *Falco peregrinus*, survey. Canadian Field-Naturalist 104(2): 182-192.

Results of Peregrine Falcon (*Falco peregrinus*) surveys carried out in 1985 and 1986 breeding seasons were used to assess the status of this species in Canada. Northern and west coast populations are stable or increasing. A new high number of nestings was reported in southern Canada. Comparison to the results of similar surveys in 1970, 1975 and 1980 shows the species is continuing to recover from the dramatic population decline it suffered prior to 1970, although numbers remain low in southern Canada.

Key Words: Peregrine Falcon, *Falco peregrinus*, populations, surveys.

Les inventaires des populations de Faucons pèlerins durant les saisons de reproduction 1985 et 1986 ont été utilisés pour établir la situation de cette espèce au Canada. Les populations du nord et de la côte ouest sont stables ou en croissance. Un nombre record de nids a été enregistré au sud du Canada. Une comparaison avec les inventaires de 1970, 1975 et 1980 montre que cette espèce continue de se remettre du déclin spectaculaire que les populations ont subi avant 1970, bien que celles-ci restent faible dans le sud du Canada.

Mots clés: Faucon pèlerin, *Falco peregrinus*, population, inventaires.

Peregrine Falcon (*Falco peregrinus*) surveys were carried out across Canada during the 1985 and 1986 breeding seasons. This report combines the results of these surveys to describe the status of this species in Canada. Similar surveys have been made at five-year intervals beginning in 1970 (Cade and Fyfe 1970; Fyfe et al. 1976; White et al. *this issue*). The 1970 survey documented severely reduced populations across Canada and Alaska and predicted possible extirpation of the species within the decade. The 1975 survey showed the Canadian population in continued decline. Results of the 1980 survey allowed guarded optimism; many population densities had improved and productivity was higher. In general, populations appeared to have stablilized, with decreases and increases on the local level.

The results of the 1985 and 1986 surveys are encouraging. More nestings, especially by captive-released birds, were reported in the eastern part of the *F. p. anatum* range (Figure 1). than in any previous survey. *F. p. anatum* populations in the Northwest Territories and the Yukon Territory were stable or increasing, although 1986 was an unproductive year for the northern Alberta population. *F. p. tundrius* populations in the Northwest Territories appeared to be reproducing at normal rates, but the single *F. p. tundrius* population in Yukon Territory was extirpated. Because of the increasing frequency of observations of captive-released birds, some information on captive-release programs in the provinces and the Yukon Territory is included here, although no attempt has been made to evaluate these programs.

Eighteen areas in seven provinces and the two territories were surveyed by provincial and national governmental agencies and private groups. Three were surveyed in 1985, 13 in 1986 and 2 in both years. Neither Manitoba nor Saskatchewan was surveyed but observations of peregrines occupying territories were recorded in both provinces. Because all areas were not surveyed in the same year, it is possible that birds moving from one survey area to another might have been counted twice or not at all. This is considered so rare as to be inconsequential because of nest-site fidelity, except where survey areas are very close together.

Surveys across the range of *Falco peregrinus anatum* are reported here in detail because of the endangered status of this subspecies and the efforts invested in its reintroduction. Surveys of *F. p. tundrius* and *F. p. pealei* are described more briefly.

Summaries of surveys conducted include information on survey methods, survey results, other noteworthy observations of peregrines in 1985-1986, comparison with results of previous major surveys, and information on captive-release programs and population trends.

Methods

Breeding surveys of raptors are difficult. Several authors have described the errors, inherent biases,

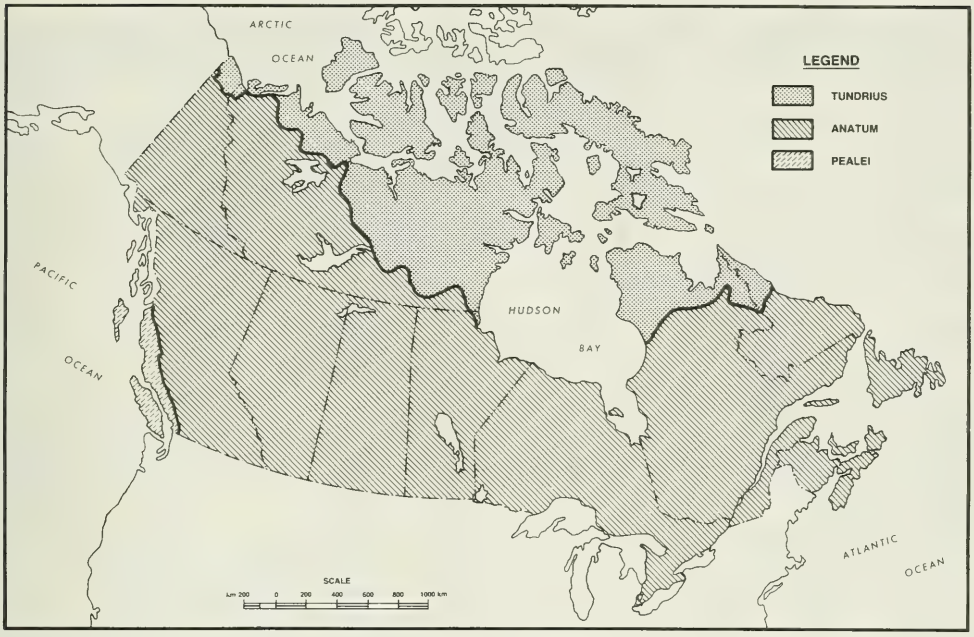

FIGURE 1. Known breeding distribution of the Peregrine Falcon in Canada (from Canadian *anatum* Peregrine Falcon Recovery Plan).

lack of comparability, and other shortcomings (Brown 1974; Postupalsky 1974, 1981). Newton (1979) pointed out that raptors make poor subjects for study of population dynamics because they breed at low densities, often in remote and inaccessible places, and are frequently subject to human interference.

In analysing and consolidating the data from the surveys, discrepancies in survey terminology, choice of population parameters, and methods for

TABLE 1. Survey Terminology and Definitions.

Term	Definition	Comment(s)
Nest Site	The actual site of the nest.	More than one alternate nest site may be present within a single territory.
Occupied Nest Site or Territory	A nest site or territory occupied by one or two territorial adults during all or some part of the breeding season.	The terms *active site* and *active territory* have been used to describe such a diversity of situations that they have become meaningless and raptor biologists should avoid using them.
Breeding Pair	A pair which laid at least one egg.	
Productive Pair	A pair which raised at least one chick to fledging, or, if actual fledging was not proven, raised at least one chick to an advanced stage of development from which the chick was assumed to have fledged.	For the purpose of Canadian surveys this term is more useful than the term *Successful pair* and its definition "a pair fledging at least one young", because it is often impossible to determine from infrequent aerial surveys whether nestlings fledge or not. C. Shank offered this definition based on the observation that nestling mortality is low from halfway through the nestling period to fledging. Brown (1974) identified the early part of the nestling period as one of the two times of strain in the breeding cycle of raptors. During this critical time only the male is available to obtain food for the young and the female. Later, food suply for the young is more assured because both parents hunt for the young and themselves.

TABLE 2. Survey effort, 1985 or 1986, *F. p. anatum*.

Area	Year of survey	Number of historical sites known in survey area†	Number of historical sites checked	Other areas/sites checked	Total number of non-urban sites checked
Labrador	1985	2	2	8 reported sites checked; other habitat surveyed incidentally	10+
Bay of Fundy	1986	14	14	all cliffs along Bay of Fundy	14+
Quebec	1985	10	6*	+ urban areas	91*
Ontario	1985	35	35	23 + urban areas	58
Manitoba	no survey	0	0	urban areas	0
Saskatchewan	no survey	4	0	urban areas	0
Alberta South of 58°	1986	59	59	+ urban areas	59
North of 58°	1986	18	16	0	16
Yukon Territory	1986				
Porcupine River		28	10	6 new occupied nest sites found	10
Yukon River		30	29	1 new occupied nest site found	29
Peel River		28	13	1 new occupied nest site found	13
Southern Lakes		3	3	0	3
Northwest Territories					
Mackenzie Valley	1985	84-89	61	total area checked = 4500 km² 17 new occupied nest sites found	61
	1986	101-106	80	total area checked = 4500 km² 5 new occupied nest sites found	80

†Does not include sites found in survey year.
*including Montreal

their calculation, were encountered. The following discussion of these methodological concerns, as well as the issues of historical sites, non-breeding birds, timing of surveys and yearly population fluctuations, is intended to clarify the information presented in this report and contribute to the standardization of future surveys.

Survey Terminology

A major obstacle to interpretation of the survey data was inconsistent use of survey terminology. Various researchers used different terms to describe the same phenomenon; occasionally the same term was used to describe different phenomena in different survey reports. The terms and definitions in Table 1 have been reviewed by all surveyors and are used throughout this report. These terms should become standard terminology for future survey reports.

Historical Sites

As in previous surveys, particular attention was paid to historical nest sites as percent occupancy of historical sites is considered an indication of relative population size. Although this concept is valid, it is not equally applicable in all areas of Canada, as discussed below:

1). In many areas historical records of peregrines are rare, not necessarily because the species was rare but possibly because it was not observed or observations were not recorded. For example, there are only 10 documented historical nest sites in Quebec south of Ungava Bay.

2). The number of historical sites known is generally a total of sites used in many different years, including those used regularly and those used only infrequently, sites used only once in the recent past, perhaps even unsuccessfully, and sites that are no longer suitable nesting habitat because of development or disturbance. Long-term population records from Britain show that individual sites are not used with equal frequency. Ratcliffe (1980) categorized historical sites according to the average number of times used per decade.

3). Peregrines are known to use alternate nest sites within the same territory. When only one of the alternate sites is known, surveyors may or may not record observations of use of another site within the same territory as occupation of a historical territory. This new site may or may not then be considered a separate historical site.

4). Expanding and declining populations may behave differently from stable populations and from each other in their selection of nest sites. It could be misleading to assume that an expanding population will re-occupy traditional nest sites first.

It is clear that the percentage occupancy figure should only be interpreted in the context of the extent of knowledge of historical populations in a given area, and caution should be used in comparing this figure for different areas.

Non-Breeding Birds

Observations of non-breeding birds (i.e. lone adults or sub-adults and non-breeding pairs)

TABLE 3. Occupancy in survey years 1985 or 1986, *F. p. anatum*.

Area	Year of survey	Total number of territories Occupied in survey year	Territories occupied by: a lone adult	Territories occupied by: a pair	Occupancy of historical sites checked[4]	Number of urban territories occupied
Labrador	1985	2	0	2	1/2 (50%)	0
Bay of Fundy	1986	1[1]	1	1	1/14 (7%)	0
Quebec	1985	1	0	1	1/6 (10%)	1
Ontario	1985	1	1	0	0/35 (0%)	1
Manitoba	1986	1	0	1	-	1
Saskatchewan	1986	2	1	1[2]	-	1
Alberta	1986					
South of 58°		2	0	2	0/59 (0%)	2
North of 58°		6	1	5	6/16 (38%)	0
Yukon territory	1985					
Porcupine River		14			8/10 (80%)	0
Yukon River		22	N.D.[3]		21/29 (72%)	0
Peel River		12			11/13 (85%)	0
Southern Lakes		0			0/3 (0%)	0
Northwest Territories						
Mackenzie Valley	1985	45	N.D.[3]		28/61 (46%)	0
	1986	57	N.D.[3]		52/80 (65%)	0

[1]Both lone adult and pair occupied same territory.
[2]Male Peregrine Falcon mated with Female Prairie Falcon.
[3]Not determined. Surveys could not determine whether sites were occupied by lone adults or pairs.
[4]Does not include new sites found in survey year.

TABLE 4. Reproduction in "remnant" *F. p. anatum* populations[1] in Northern Alberta, Yukon Territory and Northwest Territories[1].

Area	Number of occupied territories[2]	Number of productive pairs	Average clutch size	Total young produced by productive pairs	Average no. young produced per occupied territory = productivity	Average no. young produced per productive pair
Alberta						
North of 58° - 1986	6	0	3.8 (n = 5)	0	0	0
Yukon Territory - 1986						
Porcupine River	14	11	N.D.*	29	2.0	2.6 ± 1.0
Yukon River	22	18	N.D.	50	2.2	2.8 ± 0.9
Peel River	12	10	N.D.	23	1.9	2.3 ± 0.8
Southern Lakes	0	-	-	-	-	-
Northwest Territories						
Mackenzie Valley - 1985	45	36	3.5 (n=10)	76[3]	1.7	2.1 ± 0.9
Mackenzie Valley - 1986	57	36	2.9 (n = 8)	90[4]	1.6	2.5 ± 0.9

*Not determined.
[1]Does not include data on fostered and captive-reared young.
[2]Includes territories occupied by lone adults *and* pairs.
[3]Seven of 36 broods could not be counted. Figure given is mean brood size times number of productive nests.
[4]Six of 36 broods could not be counted. Figure given is mean brood size times number of productive nests.

TABLE 5. Reproduction in "reintroduced" and Labrador *F. p. anatum* populations in survey and non-survey years[1].

Area	Year	Number of lone adults on territories	Number of pairs occuying territories	Number of breeding pairs	Number of eggs in nest	Number of young in nest	Number of young fledged
Labrador	1985*	0	2	1	4	4	3
	1986*	0	2	1	2	2	?
Bay of Fundy	1986*	1	1	0	-	-	-
Quebec	1985*	0	1	1	3[2]	0	-
	1986	1	4	3	2	2	2
					1	1	1
					3	0	0
Ontario	1985*	1	0	-	-	-	-
	1986	1	1	1	1	1	1
Manitoba	1986	0	1	0	-	-	-
Saskatchewan	1985	1	1	1[3]	2	2	0[4]
	1986	1	1	1[3]	?	?	?
Alberta							
South of 58°	1986*	0	2	2	3[5]	1	1
					4[6]	3	3

Young produced per occupied territory (productivity) (1985/86 average) = 12/23 = .52
Young produced per productive pair (1985/86 average = 12/11 = 1.1.

*indicates survey year
[1]Does not include data on fostered young.
[2]Female laid one egg in each of 3 different locations.
[3]Pair consisted of male Peregrine Falcon and female Prairie Falcon.
[4]Hybrid young replaced by 3 captive-bred *anatum* young.
[5]Edmonton
[6]Calgary

occupying nesting territories during the breeding season are very important. These instances of non-breeding are difficult to interpret as they may represent infertile birds or they may indicate that the population is expanding. For this reason, productivity calculated from all occupied territories is the most valuable parameter of reproductive success of a population (see below under "Parameters"). The proportion of territories occupied by lone birds is an indication of the size of the non-breeding adult population and may permit inferences about recruitment rates and the status of the population (Postupalsky 1974).

Unfortunately, because lone adults and pairs without eggs are less attached to the nest site than are breeding pairs, they are more difficult to count accurately. Careful observations early in the season are required to find this component of the population and to determine that pairs have not attempted, unsuccessfully, to breed in a site unknown to the observer. Repeat visits may be necessary to confirm that the bird(s) is/are actually occupying a territory. In the case of aerial surveys, when a single bird is seen on a territory, it is often impossible to determine whether the bird has a mate or not.

Timing

Fraser et al. (1983) and Postupalsky (1974) have described the biases introduced by surveys done at different stages of the breeding cycle. Surveys done at different times in different years are difficult to compare.

Yearly Fluctuations

Breeding populations of peregrines may show substantial yearly fluctuations (Court et al., this issue). The most obvious cause of these fluctuations is weather. For example, in 1986 a severe wind and rain storm in northern Alberta destroyed 9 of 19 eggs and caused one nest to be abandoned; a late storm hit the Rankin Inlet area and many *F. p. tundrius* nests failed or were abandoned. Where populations are surveyed only once every five years, the exceptional nature of any one breeding season may not be immediately obvious.

Parameters

Brown (1974), Postupalsky (1974, 1981) and Fraser (1978, *in* Postupalsky 1981) all called for the standardization of population parameters and selected productivity as the most useful parameter of breeding success. Productivity is the average number of fledging or large young per occupied nest with known outcome, or the average number of young produced or recruited into the adult population per territorial pair. Previous surveys have reported this as "young per pair". As mentioned above, non-breeding pairs and single

TABLE 6. Results of Ungava Bay surveys 1970, 1975, 1980 and 1985.

a) Occupancy

Year	Total Historic Sites	Number Historic Sites Checked	Unoccupied	Lone Adult	Pair
1970[1]	15	15	3	3	9
1975[1]	27	25	14	2	9
1980[1]	28	21	11	0	10
1985[2]	28	20	5	0	23 (8 new sites found)

b) Reproduction

Year	Pairs Checked	Pairs with young	Percent of total pairs	Total young in nests	Young per pair on territory	Young per pair with young in nest
1970[1]	9	7	78	12	1.3	1.7
1975[1]	9	9	100	16	1.8	1.8
1980[1]	10	10	100	27	2.7	2.7
1985[2]	23	19	83	61	2.7	3.2

[1]White et al. (this issue).
[2]Lepage and Caron (1986)

birds assumed to have mates are included in this calculation and should be surveyed as accurately as possible. When the actual number of young in each nest known to be productive cannot be counted, an average figure for productive nests in which young were counted can be used. This introduces an element of error, but in the case of Yukon Territory and the Northwest Territories there is no alternative. Many raptor surveys also report young per successful pair and this has been done here.

Results

Survey effort is presented in Table 2, occupancy in Table 3, and reproduction in western and eastern Canada, respectively, in Tables 4 and 5. For two regions, Ungava Bay and Alberta south of 58°, 1985 or 1986 survey results are presented along with historical survey data for 1970, 1975 and 1980 (Tables 6 and 7).

Regional Summaries

LABRADOR COAST: — J. Brazil, Wildlife Division, Department of Culture, Recreation and Youth, P.O. Box 4750, St. John's, Newfoundland A1C 5T7.

1985 Survey: In 1985, 10 reported nest sites were visited between 2 July and 14 August. Two of these were sites where breeding pairs had been observed during the 1970 survey. Other potential habitat was investigated in the course of checking the ten sites (Figure 2). About 110 km of coastline was searched intensively by boat. A pair was found breeding at the historical site in Groswater Bay, Hamilton Inlet. On 31 July the nest contained four downy chicks, one of which was dead (Table 5). No other peregrines were seen. Other observers also discovered one other pair and two single adults. The pair was observed regularly at Okak Bay, but no nest was located. Lone birds were found closer to Hamilton Inlet in

TABLE 7. Survey results 1980-1986, Alberta, South of 58°

Year	Total Number Known Territories	Number checked	Unoccupied	Lone Adults	Pairs
1970	29	29	27	1	1
1975	35	31	30	1	0
1980	53	53	53	0	0
1986	59	59	59	0	2 urban[1]

[1]Not included in 59 known territories.

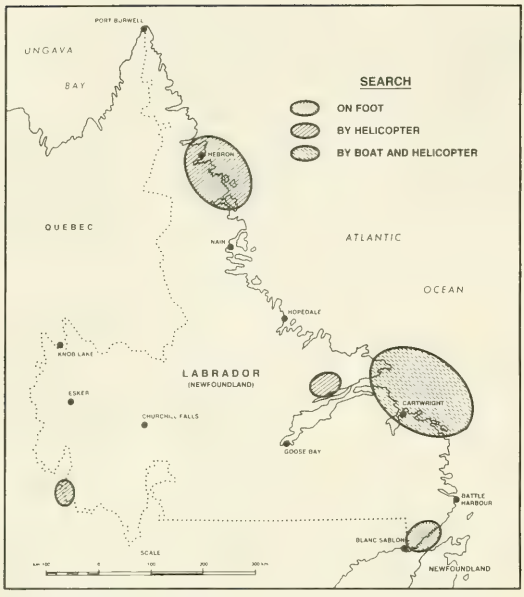

FIGURE 2. Areas in Labrador surveyed in 1985.

separate areas, but because they were only observed once during the breeding season, it was not possible to determine if they were actually occupying territories.

1986 Survey: In 1986 the coastline between Cartwright and Makkovik was surveyed systematically by boat and helicopter. The historical site in Groswater Bay was productive again; two young are believed to have fledged. Another pair was found occupying a territory at Cape Harrison on 28 July but no nest was found.

A literature search has uncovered a number of additional historical records of peregrine nestings in Labrador, but none on the island of Newfoundland. These records date back as far as 1966 and seem to indicate that historically peregrines nested along many sections of the Labrador coast and possibly inland, not just in the areas surveyed in the early and mid-seventies.

The Labrador coast was the last area in eastern Canada where peregrines are known to have nested prior to the beginning of captive-releases. During a 1970 aerial survey of 200 km of coastline and offshore islands two nests with young were discovered, but the last known record of a productive nest in Labrador is from 1971. Continued investigations of nesting territories and reported observations up to 1980 failed to find any evidence of peregrines.

The return of Peregrine Falcons to the Labrador coast between 1980 and 1985 is a hopeful sign, particularly since no releases have been made in Newfoundland and Labrador. It will be important to survey this area regularly in the future.

BAY OF FUNDY: — B. Johnson, Canadian Wildlife Service, P.O. Box 1590, Sackville, New Brunswick E0A 3C0.

On 1 July 1986 both the Nova Scotia and New Brunswick sides of the Bay of Fundy were surveyed. All known historical and potential nest cliffs were examined from a Cessna 337B aircraft. A reported inland historic site inland at Todd Mountain, York County, New Brunswick, was checked from an aircraft in late July. No peregrines or evidence of occupancy were found during these surveys.

During 1986 a captive-release pair of adult peregrines occupied a territory near a hack site in Fundy National Park but did not nest. A lone male was also present in the same territory early in the summer. This may have been the sub-adult bird from a US captive release observed at the same site in 1985.

Surveys carried out in the Maritime provinces in 1970, 1975, and 1980, including a comprehensive survey of the Bay of Fundy in 1975 and a survey of the Nova Scotia side in 1980, failed to find any evidence of current or recent occupancy at any site.

QUEBEC: — M. Lepage and M. Caron, Direction de la faune terrestre, Ministére du Loisir, de la Chasse et de la Pèche, 150 boul. St-Cyrille est, Québec, Québec, G1R 4Y3.

Southern Québec: During the last week in June through the third week in July 1985 observers on foot or in helicopter examined, on one or two separate occasions, each of 91 potential nest sites within the area of southern Québec shown in Figure 3. Six of these were historical sites and 85 were potential sites identified by examination of topographical maps and aerial photos.

The only occupied territory found in 1985 was in downtown Montreal. During the breeding season four different adults were present on this territory, including a female that laid three infertile eggs in three different locations. A team from the Macdonald Raptor Research Centre later intervened and provided two nestlings which the final pair raised to fledging.

In 1970 no evidence of peregrines was found at any historical sites, nor in two areas north of the St. Lawrence and east of Québec City selected for examination because of their abundant cliffs and potential nesting sites. The conclusion then was that the peregrine had disappeared as a breeding bird from southern Québec. Québec was not surveyed again until 1980 when approximately 54 potential and historical sites in southern Québec were surveyed and a successful nesting was documented at a historical site in the Eastern Townships.

The attempted nesting in Montreal in 1985 was the eighth recorded over the six breeding seasons from 1980-85. A total of 11 wild young and 2 fostered young were raised in these eight nests. In

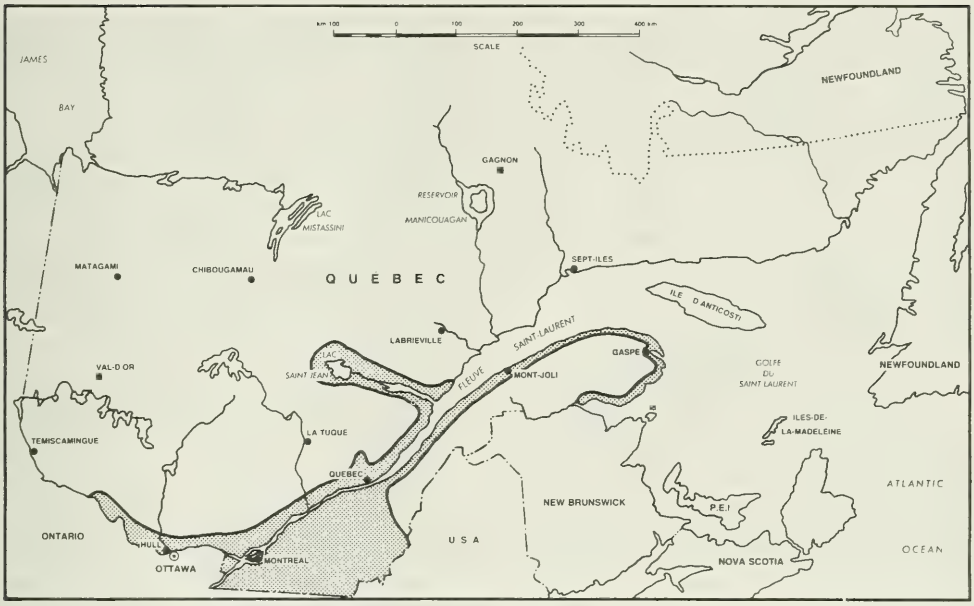

FIGURE 3. Area of southern Quebec covered by the 1985 Survey.

1986 four territories were occupied, three by pairs and one by a lone male. Two nests fledged a total of three young.

Ungava Bay: It has not yet been established whether the peregrines nesting in the Ungava Bay area belong to *F. p. tundrius* or the *F. p. anatum*.

In 1985 four areas in the Ungava Bay area were surveyed: the Gyrfalcon Islands; the Leaf River basin; the Payne-Arnaud River, from its mouth to the first rapids; and the Koksoak River, north of Kuujuaq. The Koksoak River was surveyed by canoe; all other areas were surveyed once by helicopter during the last week in July.

Survey results are shown in Table 6 together with the results of the 1970, 1975, and 1980 surveys.

The areas surveyed in the Ungava Bay region have not been the same each time, so it could be misleading to compare the survey results directly. However, the population does seem to be reproducing effectively. Note that "young per pair with young in nest" may be an over-estimate of productivity because the chicks observed were quite young.

ONTARIO: — Wildlife Branch, Ministry of Natural Resources, Whitney Block, Queen's Park, Toronto, Ontario M7A 1W3.

Areas of eastern, central and northern Ontario were surveyed between early May and late July 1985 (Figure 4). Eastern (more accessible) sites were reached by canoe; northern and central sites were reached by large boat or aircraft. Each site was visited once and whenever possible observed for five hours. Both historical (35) and potential (23) sites were visited. No evidence of nesting falcons was found at any of the 58 sites visited. A lone male occupied a territory in Arnprior.

Surveys of all known historical sites and some potential sites in 1970 and 1980, and a partial survey of historical sites in 1975 failed to discover evidence of recent or current occupancy of any sites or non-breeding individuals. As in other provinces, it is possible that peregrines are nesting or have nested unobserved in small numbers in remote areas of the province.

Although the results of the 1985 survey were not promising, encouraging finds were made in Ontario both before and after the year of the survey. In 1986 a successful nesting was documented at a non-urban site. It was not determined whether the adults were wild or captive-released birds. In 1983 a pair of peregrines nested in Arnprior. These birds had been released in Hull in 1980 and 1981. Unfortunately the female was shot and killed and the two nestlings disappeared. The male returned to the site each year up to and including 1986 but has failed to attract a mate.

MANITOBA: — Wildlife Branch, Natural Resources, Box 24, 1495 St. James St., Winnipeg, Manitoba R3H 0W9.

No survey was carried out in Manitoba in either 1985 or 1986. If Manitoba ever had a peregrine population it was probably very small. White et al. (this issue) were unaware of any confirmed nest

FIGURE 4. Areas of Ontario covered by the 1985 Survey.

records for the province but Bechard (1981) reported a clutch of peregrine eggs collected near Gladstone, Manitoba, in 1887. No surveys have been conducted in Manitoba, with the exception of a brief unproductive survey in 1980 of an area of possible habitat along the lower Churchill River.

In 1986, a pair of captive-released adult Peregrine Falcons was resident in downtown Winnipeg for more than six weeks and went through the motions of courtship, although no eggs were laid (Table 3). The female had been hacked in 1983 from the Montreal area, the male from Winnipeg in 1984. Unfortunately the male suffered an untimely death in a collision with a window or a wire.

SASKATCHEWAN: — Lynn Oliphant and Betsy Haug, Saskatchewan Cooperative Falcon Project, Department of Veterinary Anatomy, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0.

No survey was carried out in Saskatchewan in 1985 or 1986. There are few confirmed records of peregrine nests in the province. Neither a 1970 survey of suitable habitat in southwestern Saskatchewan nor a 1980 survey of a promising area north of Lake Athabasca turned up any evidence of breeding peregrines. However, recent sightings during the breeding season made by reliable observers in the area surrounding Uranium City (Lake Athabasca) continue to suggest a small population in that area (L. Oliphant, personal communication).

In 1985 a Saskatchewan rural-released male (1980) paired with a Prairie Falcon (*Falco mexicanus*) at a historical Prairie Falcon eyrie along the South Saskatchewan River (Table 3). Two hybrid young hatched and were removed and replaced by three captive-bred young peregrines, which were raised to fledging. In 1986 the young at this eyrie were found to be non-hybrid Prairie Falcons. A female peregrine was seen in the area several times.

In April 1985 a lone adult male peregrine took up residence in downtown Saskatoon. He remained for the breeding season and fostered several captive-bred young to fledging. After returning in 1986 he was joined briefly by two females in sequence, each of which left before laying any eggs. He again successfully fostered several young.

ALBERTA: — G. Erickson, Fish and Wildlife Division, Department of Forestry, Lands, and Wildlife, 9945-108 St., Edmonton, Alberta T5K 2C9.

Alberta was surveyed in 1986. As in past surveys (1975 and 1980) that part of the province south of 58° was considered separately from the northern part.

Alberta South of 58°: Between 16 and 19 May 1986 a survey of all known historical sites (59) and other potential and reported sites was conducted by helicopter. No peregrines were observed. One hundred and thirty-one young captive-reared peregrines have been released over the period 1976-1985 in central and southern Alberta. Single pairs have established in the urban centres of Calgary and Edmonton, and all four adults are from the captive-release program (Table 5). The Edmonton pair established a territory in 1981 and nested in 1982; the Calgary pair established a territory and nested in 1984. Pairs at both these locations successfully fledged their own young in 1986.

Surveys documented the disappearance of breeding peregrines from natural habitat in southern Alberta and their re-appearance in urban centres (Table 7). Prior to the urban nestings the last confirmed successful nesting occurred in 1972 (Fyfe et al. 1976).

Alberta North of 58°: This area includes the only known remnant population of Peregrine Falcons in the prairie provinces. It has been intensively managed to maximize production since 1971 and surveyed annually since 1969. In no way can the results from this area be considered representative of a natural population.

Over the period 1975-1986, 95 captive-raised young have been fostered to wild parents. Other manipulations have included double-clutching and the use of dummy eggs to keep pairs on sites until captive-reared young were available for fostering. Banded birds form a significant portion (55% in 1986) of the adult population and captive-released birds breed regularly in the study area.

In May and June of 1986, sixteen of the 18 distinct peregrine territories previously identified

were ground-checked. (Two territories not surveyed are known to have been unoccupied over the period 1974 to 1985.)

One territory was found occupied by a single male and five territories were found occupied by adult pairs (Table 3). All pairs laid eggs producing a total of 19 eggs. Five eggs were removed for pesticide analysis (one per nest), nine were lost or destroyed during a severe wind and rain storm in May and one nest was abandoned as a result of the storm. Only two eggs hatched, both from the same nest. Eight young from the captive-breeding facility at Wainwright were fostered to three of the pairs. Of the 10 young, only 3 survived to fledging. Four are believed to have succumbed to predators (including the two wild young), one was injured and subsequently euthanized, and two died of unknown causes.

BRITISH COLUMBIA: — W. T. Munro, Wildlife Branch, Ministry of Environment and Parks, Victoria, British Columbia V8V 1X5.

Coastal populations of *Falco peregrinus pealei* in British Columbia were investigated in the Queen Charlotte Islands, Gulf Islands, and northern Vancouver Island in 1986. Each area was surveyed once during the breeding season by boat and/or helicopter; therefore only data on occupancy are available. Surveyors estimated at least 57 occupied territories in the Queen Charlotte Islands, four in the Gulf Islands, and nine on northern Vancouver Island (Checleset to Gordon Channel).

YUKON TERRITORY: — D. Mossop, Fish and Wildlife Branch, Dept. Renewable Resources, P.O. Box 2703, Whitehorse, Yukon Territory Y1A 2C6.

In the Yukon Territory there are five distinct subpopulations of Peregrine Falcons, each occupying different drainage basins separated by extensive mountain ranges. The subpopulation inhabiting the arctic coastal drainage is considered to be *F. p. tundrius*, and the four others, considered to be *F. p. anatum*, inhabit the Porcupine, Yukon, and Peel River drainages, and the nesting habitat associated with larger lakes in the southern portion of the territory. All of the subpopulations have been surveyed regularly since 1973, although some have been investigated more frequently than others. Over the period 1973-1986, they have demonstrated different population dynamics.

In 1986 each of the five populations was surveyed once or twice during the breeding season, either by helicopter or by boat (ground survey). The Yukon River population was surveyed from the ground at regular intervals during the breeding season. All or most of the known historical sites in each area were checked.

Population Trends

Porcupine River Drainage: The first evidence of a population recovery in the Yukon was reported in this area in 1981. Occupancy has remained high since then and productivity, though highly variable, is probably normal for these high-latitude *anatum* birds.

Yukon River Drainage: Since 1980 this population has increased dramatically. In 1978 one nest was found, in 1986, 22 territories were occupied (Table 4). Active sites now outnumber formerly known historic sites almost 2:1. An equally striking increase has been documented in adjacent areas of Alaska.

Peel River Drainage: This population has not been monitored as effectively as the above two. In the 1980 and 1981 surveys there was evidence of only a remnant group with very low productivity. In the 1986 survey 72% of nesting sites checked produced young and two newly-occupied nesting territories were identified. This could represent an increasing trend in the population.

Southern Lakes: This population is believed to be extirpated. It has been poorly known but visits to historic sites have failed to discover any evidence of occupancy.

Arctic Coastal Drainage: (*F. p. tundrius*) Annual surveys since 1980 have covered most of the former range and all known historic sites. A dramatic decline has been reported. It is believed that the population ceased to breed in 1981, and no adults have been observed since then.

NORTHWEST TERRITORIES: — C. Shank, Wildlife Population Management, Department Renewable Resources, Yellowknife, Northwest Territories X1A 2L9.

Both *F. p. anatum* and *F. p. tundrius* inhabit the Northwest Territories. The *F. p. anatum* population inhabits the Mackenzie Valley.

Anatum Population: The Mackenzie Valley has been surveyed for Peregrine Falcons annually since 1969, except 1983 (Bromley and Matthews, 1988).

In 1985 and 1986, intensive helicopter surveys were made of the Mackenzie Valley between Norman Wells and Inuvik. In both years, a first survey was made in mid-June to document egg-laying followed by a second survey in mid-to-late July to quantify production. Each survey covered approximately 4 500 km^2 checked most but not all historical sites. Survey effort was equivalent in both years. Seventeen new nest sites were found in 1985 and five in 1986 bringing the total number known in the Mackenzie Valley to somewhere between 101 and 106.

Bromley and Matthews (1988) recently analysed the results of annual Mackenzie Valley peregrine surveys from 1969 to 1985. They concluded that the peregrine population declined by approximately

35% in the late 1970s but returned to earlier levels by the mid-1980s. They found a parallel trend in the proportion of occupied sites where young were produced, but no observable trend in the mean number of young per productive nest. By 1985 the rate of population increase appeared to be declining or the population was levelling off at a slightly lower level than during the early to mid-1970s. However, the 1986 occupancy of known sites (65%) and the calculated production of 90 young were higher than any previously recorded, which suggests the population may still be increasing.

Tundrius Population: Bromley (1988) summarized the data available on populations in the Kitikmeot, Baffin, and Keewatin regions for the period 1982-1985. He concluded that all areas surveyed supported populations reproducing at normal rates.

In 1986, *tundrius* peregrines were surveyed at Rankin Inlet (for the sixth year) and in the Kitikmeot region. Birds at both areas showed depressed reproductive success as a result of abnormally bad weather.

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Status of the Peregrine Falcon, *Falco peregrinus pealei*, on Langara Island, Queen Charlotte Islands, British Columbia, 1968–1989

R. Wayne Nelson

4218 - 63 Street, Camrose, Alberta T4V 2W2

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From 1968 to 1989, Langara Island, British Columbia, held 5-7 territorial pairs of Peregrine Falcons (*Falco peregrinus pealei*). Annual production from the island varied greatly. In 1968-1979, it averaged 9.1 nestlings per year (range 5-13), and in the 1980s it averaged 14.1 (range 8-20). Disappearance (presumed mortality) of known territorial birds averaged 26% per year for males and 37% per year for females, higher than in five other studies of turnover in breeding Peregrines. Levels of DDE in falcon eggs in 1968-1972 were somewhat below the level that results in population decline. By 1986 the DDE had dropped to less than half of its former level. During the same period the PCB in eggs remained unchanged at moderate levels. The Langara Island nesting population of the Ancient Murrelet (*Synthliboramphus antiquus*), primary prey of the falcons, declined from very large numbers (probably well over 250 000 pairs) in the 1950s and earlier, to 80 000-90 000 pairs in 1971, to 22 000-24 000 pairs in 1981 and 1988 surveys. Several possible causes of the murrelet decline are outlined, including changes in the ocean and predation by introduced rats. Between 1957 and 1968 the falcon population declined from 20+ pairs to 5 pairs and then remained at 5-7 pairs through the 1970s and 1980s despite the further decline in the murrelet population. Although the number of pairs of falcons in earlier years appeared closely tied to the number of pairs of murrelets nesting on the island, from about 1968 onwards the Langara Island falcons apparently "relied" not on locally nesting murrelets but on murrelets commuting from distant nesting colonies. This falcon population in 1968-1989 was stable and reproductively healthy. A proposed rat eradication program might result in the recovery of the Langara Island murrelet population, and the falcon population, toward the very large numbers reported in the 1950s and earlier.

De 1968 à 1989, il y avait sur l'île de Langara, Colombie-Britannique, de 5 à 7 couples territoriaux de Faucons pèlerins (*Falco peregrinus pealei*). La production annuelle de l'île était très variable. Entre 1968 et 1979, il y eut une moyenne de 9,1 oisillons par année (entre 5 et 13), et pendant les années 80, la moyenne fut de 14,1 (entre 8 et 20). Les disparitions (mortalité présumées) des oiseaux connus du territoire furent en moyenne de 26% par année chez les mâles et de 37% par année chez les femelles, chiffres plus élevés que dans cinq autres études sur la fluctuation du nombre des Faucons reproducteurs. Le niveau de DDE dans les oeufs entre 1968 et 1972 était quelque peu en delà du niveau qui cause le déclin des populations. En 1986, le taux de *DDE* était tombé à moins de la moitié du niveau antérieur. Durant la même période, les taux modérés de BPC dans les oeufs sont demeurés constants. La population nicheuse d'Alques à cou blanc (*Synthliboramphus antiquus*) de l'île de Langara, la proie principale des faucons, très nombreuse avant et pendants les années 50 (probablement beaucoup plus de 250 000 couples), déclina à 80 000 ou 90 000 couples en 1971, et à 22 000 ou 24 000 couples aux relevés de 1981 et de 1988. Plusieurs causes possibles du déclin des alques ont été évoquées dont des changements océaniques et la prédation par des rats importés. Entre 1957 et 1968, la population de faucons déclina de plus de 20 couples à 5 couples et resta stable à 5 ou 7 couples pendant les années 70 et 80 malgré le déclin continu de la population d'alques. Même si, durant les années précédantes, le nombre de couples de faucons semblait étroitement lié au nombre de couples d'alques nichant sur l'île, à partir de 1968 environ, les faucons de l'île de Langara ne furent plus "dépendants" des alques locales, mais plutôt d'alques de passage provenant de colonies distantes. Cette population de faucons, de 1968 à 1989, était stable et se reproduisait bien. Un programme d'extermination des rats fut proposé et pourrait bien être la solution favorable au rétablissement de la population d'alques sur l'île de Langara et ainsi ramener la population des faucons au nombre important relevé pendant et avant les années 50.

Key Words: Peregrine Falcon, *Falco peregrinus pealei*, Ancient Murrelet, *Synthliboramphus antiquus*, predator-prey relationship, population dynamics, Queen Charlotte Islands.

The Peregrine Falcons (*Falco peregrinus pealei*) nesting at Langara Island, British Columbia, have been visited by naturalists and scientists since 1915 (Green 1916) and recently have provided a continuous 22-year string of occupancy and reproduction data, from 1968 to 1989. Because the falcons occupying territories at Langara Island do not migrate, and because they prey almost entirely upon small seabirds, primarily the Ancient Murrelet (*Synthliboramphus antiquus*), these falcons were only relatively lightly impacted during the 1950s-1970s by the DDE-thin-eggshell syndrome that extirpated many other peregrine populations (e.g. Hickey 1969, Cade et al. 1988). The number of nesting pairs, reproductive success, and a number of other aspects of the Langara

Island falcons have been described earlier (e.g. Nelson 1970, 1976a, 1976b, 1977, 1980; Nelson in White et al. this issue; Nelson and Myres 1976). This paper reports on the status of this falcon population from 1968 through 1989, emphasizing the 1980s, summarizes recent Ancient Murrelet population changes, and re-evaluates the falcon-seabird relationship.

Study Area and Methods

Langara Island is at the northwestern tip of the Queen Charlotte Islands off the northern British Columbia coast. The island is about 10 km long and 6 km wide, heavily forested, with many cliffs on its perimeter.

During 1968, 1969, 1971, and 1972, my wife and I resided on Langara Island for 4½ to 6 months spanning 15 February to 19 September and studied a number of aspects of the falcons' way of life. In 1976, 1978, and 1979, basic occupancy and productivity data were obtained by the British Columbia Wildlife Branch. In each of the remaining years through 1989, with an assistant I visited the island usually for 8–10 days when nestlings were of banding age. The coastline cliffs were searched for territorial falcons by foot and from an inflatable boat. Although ocean conditions and time did not allow a thorough inspection of all of the coastal cliffs each year, a majority of the historical nesting sites and all recently occupied cliffs were checked each year. Usually the territorial falcons were conspicuous. If any territorial birds were missed over the years, the number must be very small.

During the 1970s, usually the nest contents were observed only from a distance by telescope; in the 1980s most nest cliffs were climbed, nestlings were banded and various data collected. Pop-rivetted green anodized aluminum color bands with unique letter and number combinations were placed on a majority of the nestlings in each year in 1984-1989; the bands were readable by telescope to about 100 m away. In 1968-1974 and 1980-1989, adult face markings were sketched or photographed through a telescope and used to identify the adults in subsequent years to determine turnover rates (*see* Nelson 1988).

Background

Beginning with Green (1916), Nelson and Myres (1976) summarized the ornithological literature describing the relatively large numbers of peregrines and the very large numbers of seabirds nesting on this island. The best-documented early report (Beebe 1960) listed 13 falcon nesting sites on the eastern half of the island that were used in most years during 1952-1958, and the whole island probably held 21-23 pairs of falcons at that time (Nelson and Myres 1976). The numbers of Ancient Murrelets in the 1950s and earlier, although not quantified by the various authors, were extremely large; in the early years the island almost certainly held more than 250 000 pairs and probably held between 375 000 and 750 000 pairs (Nelson 1977) and possibly was the largest Ancient Murrelet colony observed in this century. A dramatic drop in the number of murrelets nesting on the island apparently began in the mid-late 1950s and caused a very marked drop in the number of falcons nesting on the island by the time this study began in 1968.

Concern for the welfare of the falcon population on the Queen Charlotte Islands as a whole prompted a review paper (Munro 1988) and a Commission of Inquiry (Shelford 1988), both of which pointed out the critical importance of the seabird populations in maintaining a strong falcon population.

Breeding Population

In each year from 1968 to 1979 the island held between 5 and 6½ territorial pairs of falcons (Nelson

TABLE 1. Occupancy and reproductive performance of Peregrine Falcons at Langara Island, British Columbia, during the 1980s.

Year	Number of pairs	Lone adult	Pairs with young	% of total pairs	Total young	Young per pair	Young per successful pair
1980	6	0	6	100	13	2.17	2.17
1981	6	0	5	83	14	2.33	2.80
1982	6	0	6	100	20	3.33	3.33
1983	7	0	5	71	13	1.86	2.60
1984	7	0	6	86	19	2.71	3.17
1985	5	1	4	80	8	1.60	2.00
1986	5	0	4	80	11	2.20	2.75
1987	5	0	4	80	13	2.60	3.25
1988	7	0	6	86	17	2.43	2.83
1989	7	0	5	71	13	1.86	2.60
Average	6.1		5.1	84	14.1	2.31	2.76

1988). During the 1980s the number of pairs fluctuated between 5 and 7 (Table 1).

During 1970-1974, apparently at the end of the population decline for the falcons on this island, at three sites a situation termed pseudo-polyandry occurred in which a paired female prevented an adjacent, recently widowed male from obtaining a new mate (see Nelson and Myres 1976). At two of these sites, first one site (1972-1973) then the other site (1974) held a female that occupied both of the males' territories; by 1975 one of the males had disappeared and, through 1989, that part of the coastline then held only one pair of falcons.

At another pair of sites, in 1972, the female at site C kept the neighboring male at site I single after his mate disappeared. However, when the site C female then disappeared, before spring 1973, both males obtained new females and then had offspring. In 1977-1978 site I was occupied; however, at site C in 1977 an adult female was briefly seen, but then drifted off, and in 1978 no falcons were found there. Both sites were occupied by pairs in 1979-1984. In 1985-1987 site I was vacant; in 1988-1989 both sites were again occupied by pairs.

No instances of a single male on territory or a female exhibiting pseudo-polyandry were noted after 1974. That behavior appeared to be the means whereby the falcons enlarged their territories in response to a serious reduction in the numbers of their prey.

In 1984-1985, a new pair was present at site A but produced no offspring. Only the female was found in 1986, and the site appeared vacant thereafter. Nearby, in 1988 at site D a new pair was found and that site produced nestlings in 1988 and 1989. Both of these sites were historic sites that had not been active since the mid-1960s.

The territorial behavior of these falcons has been investigated (Nelson 1977); they chase intruders to boundaries and fly display flights outward to, and along, territorial boundaries that are approximately midway between neighboring nest cliffs. During this study, the territories of most of the pairs included two or more formerly distinct historic nesting territories. Occasionally, however, a new pair of falcons was able to become established and one territory was split into two. In 1968-1989, the most stable situation appeared to be with 5 pairs, relatively widely spaced. The sixth site was occupied in a majority of years but in some years appeared to be incorporated within that of a neighboring pair. The seventh site (two nearby sites noted above) appeared to be more ephemeral and held a pair in only 4 years. This situation appeared to be normal. Under natural conditions peregrine populations elsewhere are remarkably stable and over a number of years show only minor fluctuations in the number of breeding pairs (often within 8% of the mean: Ratcliffe 1980:78).

Productivity

In a majority of years in the 1980s, only one pair failed to produce nestlings, twice two pairs had no nestlings, and twice all pairs had nestlings (Table 1). In 1968-1979 on the whole island the annual production averaged 9.1 nestlings (range 5-13). In the 1980s, however, the annual production from the whole island averaged 14.1 nestlings (range 8-20) and only twice was less than 13 nestlings. Production in 1982, 1984, and 1988 was especially good (Table 1).

During the 1980s, the number of young per territorial pair was less than 2.0 during only 3 years in 10 (Table 1). During 1968-1979, however, there were less than 2.0 young per pair in 9 of 12 years. Similarly, during the 1980s the number of young per successful pair fell below 2.6 during 2 years in 10, in contrast to falling below 2.6 during 9 of 12 years in 1968-1979. It is suspected that weather factors were responsible for the larger brood sizes that were found at banding time in the 1980s, but statistical examinations have so far failed to detect any significant correlations between weather factor(s) and the average brood size or the total number of nestlings on the island in a given year.

Survival of Breeders

At Langara Island, territorial falcons that reared 3-4 nestling ($n = 44$) disappeared from one year to the next at a rate of 43%, versus only 23% for territorial birds that reared only 0, 1, or 2 nestling ($n = 60$) ($0.90 < P < 0.95$; Chi-square test). This suggests that when conditions result in a brood of 3 or 4 nestlings the adult falcons provide optimal care for those nestlings, absorb the additional costs of the larger brood, enter the following winter in poorer condition, and experience higher mortality rates (Nelson 1988). Overall annual loss of males was 26% and for females was 37% ($n = 47$ and 57 falcon-years respectively). These mortality rates were higher than any others recorded for peregrines (e.g. Mattox and Seegar 1988; Newton and Mearns 1988; Ambrose and Riddle 1988; Enderson and Craig 1988; Court et al. 1989) and probably resulted from the facts that the nesting falcons were resident year-round on the island and had to hunt seabirds over the ocean during very hostile winter conditions. Only in 1969 and 1980 did a yearling female occupy a nest cliff on the island. In several years, over half of the adults recorded in one spring had disappeared and were replaced by the next spring, indicating that the productivity of this and nearby areas was good and that a substantial population of floaters (non-breeding adults) was available to replace lost breeders.

Biocides

Nine falcon eggs (2 fresh, 7 addled) taken in 1968-1972 averaged, in parts per million (ppm) wet weight (range): DDE, 17.6 (10.9–25.7); and PCB, 11.0 (3.24–35.5). The addled eggs were approximately 25% lighter in weight (dehydrated) than the fresh eggs and so the organochlorines were somewhat concentrated. When "corrected" to fresh-laid moisture levels (Nelson and Myres, unpublished), the nine eggs averaged: DDE, 13.9 ppm (10.9–20.2); and PCB, 8.44 ppm (1.88–22.9).

Eight of the eggs provided eggshell thickness indices which averaged 12.6% (4.2–19.9) less than pre-DDE eggshells from the Canadian west coast (pre-1947 data of Anderson and Hickey 1972; 91 eggs from Q.C.I., 80 of those from Langara). During 1968-1972 a small number of falcon eggs at Langara Island disappeared during incubation, and a number of others failed to hatch, but the productivity was adequate to sustain the breeding population (Nelson and Myres 1976). DDE levels of 15–20 ppm in Peregrine eggs are associated with reductions of 15–20% in the eggshell thickness index and the eggshell thickness itself. With more than that amount of eggshell thinning, too many eggs are broken, too few young are reared, and the population is unable to sustain itself (Fyfe et al. 1988; Peakall and Kiff 1988).

In 1986, four addled eggs from two nests averaged: DDE, 5.86 ppm (5.26–6.59); PCB, 8.58 ppm (7.97–9.80); beta-BHC, 0.472 (0.424–0.559); heptachlor epoxide, 0.040 (0.037–0.043); and dieldrin, 0.028 (0.023–0.036). From 1968-1972 to 1986, in falcon eggs the amount of DDE dropped to less than half and the amount of PCB remained the same. The 1986 levels of DDE were low enough that eggshell breakage would be a relatively rare event (see Nelson 1976b; Fyfe et al. 1988; Peakall and Kiff 1988).

Prey Base

Earlier (Nelson 1976a, 1977, 1983) I suggested that (a) the stability fo the falcon breeding population at Langara Island since 1968 showed that the population of Ancient Murrelets on the island was also stable during this period, and (b) any further changes in this murrelet population would be reflected in parallel changes in the falcon population nesting on the island. Based on the 1971 estimate by S. G. Sealy (*in* Vermeer et al. 1984) of 80 000–90 000 pairs of Ancient Murrelets on the island, it appeared that each pair of falcons required between 13 000 and 22 000 pairs of murrelets to indefinitely sustain its harvest of roughly 1000 murrelets annually, plus provide a protective buffer against overharvesting (Nelson 1977, 1983).

Detailed surveys of the murrelet population in the 1980s forced rethinking of details of this hypothesis. In 1981, Rodway et al. (1983), and Vermeer et al. (1984) used extensive searches, transects, and plots to locate the remaining colony areas, determine nesting burrow density, and estimate the total population of 22 500 pairs. In 1988 a more detailed survey was carried out, primarily in the main colony area located in 1981 (Bertram 1989). This survey estimated 24 000 pairs ± 4 000 (standard error) and showed that the colony occupied a smaller area but at a greater density of nesting burrows. Several lines of evidence suggested that the predation on murrelets by the long-established Alexandrian Rat (*Rattus rattus alexandrinus*) may have been an important factor in the population decline of the murrelets (Bertram 1989).

Although it seems clear that the murrelet decline on the island between the mid-1950s and 1968 was responsible for a parallel decline in the falcon population, after 1968 the falcon population remained stable and did not parallel the further decline of the murrelets (by 60–75%) between 1968-1971 and the 1980s. Why did the falcon population not decline further? Were rats actually responsible for the murrelet decline in the 1950s-1960s and more recently?

Falcon-Seabird Relationships

In the Aleutian Islands, Alaska, Amchitcka Island contained 16-22 occupied falcon territories in 1968-1973 (White 1975). The nearest significant seabird colonies were on adjacent islands more than 20 km away, and yet a majority of the diet of the nesting falcons was composed of seabirds, apparently taken in offshore hunting flights. The falcon nests tended to be closer together at the ends of the island, probably because seabirds tended to be funnelled past the ends of the island. A similar situation appears to have existed at Langara Island since some time just prior to 1968. At that time the reduced falcon population probably was capturing primarily offshore, commuting murrelets instead of locally nesting murrelets, and a further decline in the murrelets nesting on Langara Island would not cause a further decline in the falcon population.

Frederick Island, 33 km south of Langara Island, in 1980 was estimated to be inhabited by 68 400 ± 8 114 pairs of Ancient Murrelets and by 89 850 ± 13 169 pairs of Cassin's Auklets (*Ptychoramphus aleuticus*) (Vermeer and Lemon 1986). That island has held 3, and occasionally 4, pairs of falcons (W. Munro, personal communication) and has potential nest cliffs and space to allow for at least six pairs if the food supply were more abundant and falcon territories consequently smaller (personal observations).

Forrester Island and adjacent islets, Alaska, are 65 km north of Langara Island. In 1969, 7 pairs of falcons were found here (F. Robards *in* White et al.

1976) and in 1976 five pairs were seen (DeGange and Possardt *in* Sowls et al. 1978) although in 1976 the entire coastline was not thoroughly searched (T. DeGange, personal communication). In 1976 these islands were estimated to contain 33 800 pairs of Cassin's Auklets, 30 000 + pairs of Ancient Murrelets, 389 000 pairs of Fork-tailed and Leach's storm-petrels (*Oceanodroma furcata* and *O. leucorhoa*), 54 000 pairs of Rhinoceros Auklets (*Cerorhinca monocerata*), and 41 800 pairs of Tufted Puffins (*Fratercula cirrhata*) (Sowls et al. 1978). The Rhinoceros Auklet may be rather heavy for a male Peregrine Falcon to carry and it probably is seldom captured by males when the other species are available.

Each falcon requires about 200 g of prey per day, or approximately one Ancient Murrelet, one Cassin's Auklet, four storm-petrels, one-half a puffin, or one-half a Rhinoceros Auklet per day per falcon. On this basis, at Frederick Island in 1980 each falcon territory represented approximately 53 000 pairs of murrlets and auklets (ca. 21 200 kg). At Forrester Island, if we consider all six prey species and assume that the whole island complex held 7 pairs of falcons, each falcon territory in 1976 represented approximately 50 400 pairs of "Ancient Murrelet equivalents" (ca. 20 160 kg).

From these various lines of evidence it is clear that the earlier peregrine:murrelet ratio of 1 pair: 13 000–22 000 pairs for Langara Island (based on the 1971 estimate of murrelet numbers) did not represent a sustainable predator-prey relationship, and the 5–7 pairs of Langara Island falcons at that time and through the 1970s and 1980s were primarily relying on murrelets from more distant colonies. From the foregoing it also is evident that, if the Ancient Murrelet were to disappear as a nesting species from Langara Island, there probably would remain 5–7 nesting pairs of falcons on that island, provided that the Frederick and Forrester Island seabird colonies remained relatively stable and continued to provide seabird prey that were available to the Langara Island falcons.

Cause(s) of the Seabird and Falcon Declines

Bertram (1989) found considerable evidence of rat predation upon adult Ancient Murrelets and their eggs on Langara Island in 1988 and suggested that rats may have caused the murrelet decline. Beebe (1953) may have been the first to report rats on the island, and he (1960) and other authors (e.g. Nelson and Myres 1976; Vermeer et al. 1984) suggested that the effect of the rats on the murrelet population was not especially serious. It appears to be unknown when rats became established here, perhaps with the very active Sea Otter trade in this area in the early 1800s, as a result of the establishment of Langara Lightstation in 1913, with the supplying of two radar stations on the island during World War II, or several commercial fishing camps in the 1940s and 1950s. It is not conclusively shown that rats were the primary factor in the murrelet and falcon declines. Could the murrelet population, ashore for only a few months each year, simply have swamped the rat population? One particular difficulty with the rat predation/murrelet decline hypothesis is this: if rats brought the murrelet population from roughly 1/2 million pairs or more down to 80 000–90 000 pairs between, say, 1955 and 1971, and from 80 000–90,000 pairs to about 22 500 pairs between 1971 and 1981, then why were the rats unable to seriously deplete or eliminate the murrelet population between 1981 and 1988?

In the data of Beebe (1960; *see* Nelson and Myres 1976) there was evidence that the falcon population entered serious decline on Langara Island in 1958 when 5 of 13 sites were unoccupied. Of interest is the fact that the number of pairs in the Glaucous-winged Gull (*Larus glaucescens*) colony and the Pelagic Cormorant (*Phalacrocorax pelagicus*) colony near Langara Lightstation in 1958-1959 dropped to 1/2–1/3 of their previous numbers of nests (Drent and Guiguet 1961), and through the 1980s those colonies remained at roughly 1/2 of their earlier size (unpublished data). This suggests that a relatively permanent change in the ocean-based food supply occurred about 1958-1959. In 1957-1958 the NE Pacific Ocean warmed considerably, and this general area had warmer than normal waters into the 1970s (Nelson and Myres 1976). In the late 1970s and the 1980s the western Canadian ocean temperatures were particularly warm (Freeland 1990, personal communication). This change may have markedly affected food abundance or availability for murrelets, cormorants, and gulls.

Another change, in the salmon stocks near Langara Island, occurred such that a thriving fishery was reduced through the 1960s and then seriously cut back during the 1970s. Long-time fishermen commented in the early 1970s regarding the much reduced abundance of surface "boils" of small fish versus earlier years. These "boils" often had salmon associated with them, and possibly were caused by the salmon attacking the schools of small fish and forcing them to the surface — where they were easily visible to and vulnerable to the various seabirds. Perhaps fewer salmon resulted in fewer surface "boils", reduced availability of food to the seabirds, and reduced numbers of nesting seabirds.

Although it is recognized that rats on Langara Island are a significant but unquantified mortality factor for the Ancient Murrelets nesting there, the real role of the rats in the murrelet decline is not clear. There is also evidence that oceanic factors may

have been responsible for the initial murrelet decline, and indirectly for the falcon decline. Perhaps rat predation was then able to overwhelm the reduced murrelet population, and drive it downward. However, the apparent relative stability of the Langara Island murrelet population through the 1980s confuses the matter.

The Canadian Wildlife Service and the British Columbia Wildlife Branch are investigating the feasibility of a rat eradication program on Langara Island (W. Munro, A. Edie, personal communication). Such an experiment could be very difficult and costly, but it would be extremely valuable in clarifying the recent effects of the rats upon the murrelet population, and, if successful, it could allow the Ancient Murrelets, other seabirds, and Peregrine Falcons to rebuild to the truly spectacular numbers observed on Langara Island in the 1950s and earlier.

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Preliminary Report on Breeding Peregrine Falcons, *Falco peregrinus*, in Labrador: 1987 and 1988 Survey Results

D. LEMON[1] and J. BRAZIL[2]

[1]Natural History Society of Newfoundland and Labrador, P.O. Box 1013, St. John's, Newfoundland A1C 5M3
[2]Newfoundland Wildlife Division, Building 810, Pleasantville, St. John's, Newfoundland A1C 5T7

Lemon, D., and J. Brazil. 1990. Preliminary report on breeding Peregrine Falcons, *Falco peregrinus*, in Labrador: 1987 and 1988 survey results. Canadian Field-Naturalist 104(2): 200–202.

Surveys were conducted in 1987 and 1988 to locate breeding Peregrine Falcons (*Falco peregrinus*) in Labrador. Active nests were located in a variety of habitats comprising coastal areas, including offshore islands and fiords, and interior river valleys. Seven active Peregrine Falcon nest sites have been located in Labrador.

Key Words: Peregrine Falcon, *Falco peregrinus*, Labrador, active nests.

Des études ont été menées en 1987 et 1988 pour repérer des Faucons pèlerins nicheurs (*Falco peregrinus*) au Labrador. Des nids occupés ont été localisés dans plusieurs habitats qui comprennent la région côtière, incluant les îles et les fjords élognés du littoral, ainsi que les cours d'eau à l'interieur des terres. Sept nids occupés de Faucons pèlerins ont été repérés au Labrador.

Mots clés: Faucon pélerin, *Falco peregrinus*, Labrador, nidification.

In response to national management and conservation efforts directed toward the recovery of Peregrine Falcon, *Falco peregrinus*, populations in Canada, a need for surveys to locate breeding Peregrine Falcons in Labrador was identified. Prior to 1987, the Newfoundland Wildlife Division conducted small scale surveys along the portions of the coast and other surveys on an *ad hoc* basis to address this need (Joe Brazil, personal communication). In 1987 and 1988 the Natural History Society of Newfoundland and Labrador coordinated funding and logistics from a variety of government and non-government agencies enabling large scale, systematic helicopter surveys of the Labrador coastline and interior regions to be conducted.

The baseline Peregrine Falcon population data obtained from these surveys represents the most current information on the Labrador population and should provide wildlife researchers and managers with valuable information on which to base conservation and management efforts.

The area that has been surveyed by helicopter (Figure 1) is described in detail by Lopoukhine et al. (1977) and comprises primarily steep fiords, vast U-shaped river valleys and upland plateaus, steep cliffs exceeding 500 m in height and numerous offshore islands. Prior to the surveys, potential areas that might support nesting Peregrine Falcons were identified using 1:250 000 topographic maps. After commencing the surveys, the survey route chosen depended on the suitability of the immediate habitat. Survey routes were selected on a daily basis once the field work commenced. All surveys were conducted using a Bell 206L helicopter with three observers in addition to the pilot. Cliff areas that appeared to offer potential Peregrine Falcon nesting habitat where searched from the helicopter travelling at 70-100 km/h while trying to maintain a distance of approximately 50 m from the cliff. When an adult Peregrine Falcon was observed, an intensive search of the immediate and adjacent cliff area was conducted in an attempt to locate a nest site.

In 1987 and 1988, 1204 km and 666 km of potential Peregrine Falcon nesting habitat was surveyed respectively (Figure 1). In 1987, three active Peregrine Falcon nests were located during this study and one additional nest site was located near Cartwright, Labrador during fieldwork in an unrelated study (Department of National Defence environmental research). The active nest site near Cartwright has been monitored since 1985 by the Newfoundland Wildlife Division following initial identification in the early 1970s (Cade and Fyfe 1970). In 1988, three active Peregrine Falcon nests were located during this study. A total of seven active Peregrine Falcon nest sites have been located in Labrador in the past two years. Table 1 provides a detailed description of the seven nest sites located in Labrador during the past several years.

Our 1987 and 1988 survey results are intended to provide current information on the baseline population estimates of the Peregrine Falcon in eastern Canada for regional and national management and conservation efforts.

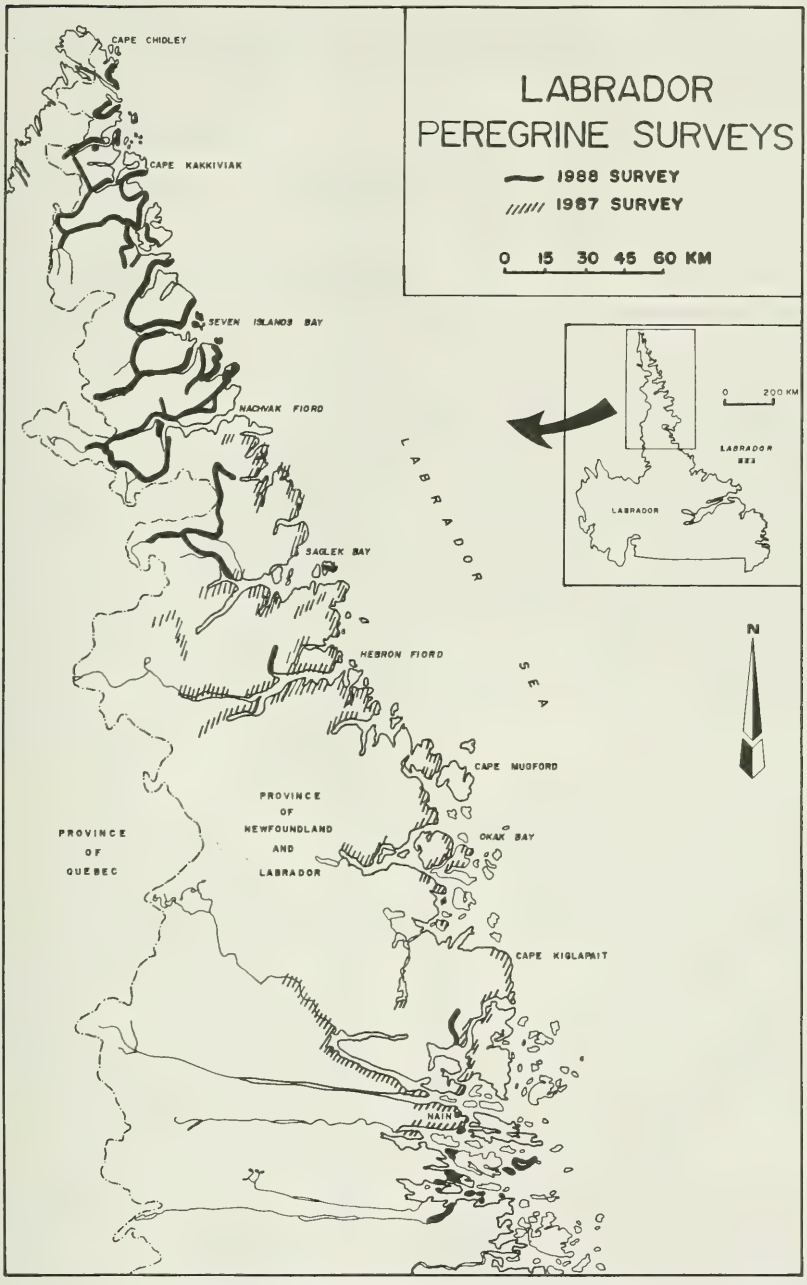

FIGURE 1. Areas in Labrador surveyed in 1987-1988.

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TABLE 1. Peregrine Falcon nest site characteristics in Labrador.

Nest	Height above ground/water(m)	Height of cliff/hill(m)	Aspect	Nest site area	Number of eyases	Age of eyases	Date of survey
1	800	1000	SSW	lake	3	10 days	7/31/87
2	150	180	E	fiord	2	4-5 weeks	7/31/87
3	140	155	SSE	coastal island	2	3 weeks	8/01/87
4	70	80	ESE	coastal island	1	—	7/23/87
5	40	60	S	coast	2	1-2 weeks	7/24/88
6	50	75	S	coastal island	3	1-2 weeks	7/24/88
7	100	140	S	river valley	2	1-2 weeks	7/25/88

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Addenda

The surveys conducted in 1987 and 1988 continued in 1989 and completed a search for breeding Peregrine Falcons along the *entire* Labrador coast. Some additional work was conducted by the Newfoundland Wildlife Division and the Department of National Defence in 1989. A total of 26 breeding pairs of Peregrine Falcons are now known to occur on the Labrador coast representing a substantial population.

DAVID LEMON

General Delivery, Topsail, CBS. Newfoundland A0A 3Y0.

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The Reintroduction of the Peregrine Falcon, *Falco peregrinus anatum*, into Southern Canada

GEOFFREY L. HOLROYD[1,2] and URSULA BANASCH[1]

[1]Canadian Wildlife Service, 2nd Floor, 4999-98 Ave, Edmonton, Alberta T6B 2X3
[2]Department of Forest Science, University of Alberta, Edmonton, Alberta T6G 2H1

Holroyd, Geoffrey L. and Ursula Banasch. 1990. The reintroduction of the Peregrine Falcon, *Falco peregrinus anatum*, into southern Canada. Canadian Field-Naturalist 104(2): 203-208.

The recovery of *anatum* Peregrine Falcon populations in southern Canada has depended upon the release of captive raised young. Between 1976 and 1987, 563 young falcons were released at 24 areas in southern Canada (an average of 5.04 young per area per year; range 1 to 16). At a minimum, 35 (6.2%) peregrines returned at least one year after their release. Paired falcons were encountered significantly further from their release site than single falcons. Females returned further from their release sites than males but the difference was insignificant. Peregrines most often returned to the same kind of site (urban or rural) from which they were released. One half of the returning birds were first observed as single birds, at one year of age, and did not return. In 1988 there were 12 territorial pairs south of the boreal forest which produced 11 young. Recommendations to improve future release efforts are made.

Le rétablissement des populations de Faucons Pèlerins *anatum* au Canada méridional dépend de la remise en liberté de jeune élevés en captivité. Entre 1976 et 1987, 563 jeunes faucons au total ont été remis en liberté dans 24 régions du Canada méridional (une moyenne de 5,04 jeunes par région par année; valeurs allant de 1 à 16). Au moins 35 (6,2%) des individus sont revenus au moins un an après la mise en liberté. Les couples de faucons reviennent de façon plus loins des sites de lacher que les individus seuls. Les femelles reviennet plus loins des sites de lacher que les mâles, bien que la différence soit insignifiante. Les Faucons Pèlerins reviennet plus vraisemblablement à des emplacements du mème type (urbains ou ruraux) que ceux dans lesquels ils ont été remis liberté. La moitié des oiseaux qui reviennent ont d'abord été observés seuls, à un age de un an, et ne reviennent que pour un an seulement. En 1988 il existait 12 couples territoriaux au sud de la forêt boréale qui produisirent 11 jeunes. Des recommendations visant à améliorer les futures remises en liberté sont présentées.

Key Words: Peregrine Falcon, *Falco peregrinus anatum*, captive release, reintroduction, Canada.

The decline of the Peregrine Falcon (*Falco peregrinus*) in the 1950s and 1960s in North America and Europe has been well documented (Hickey 1969). In Canada, by 1970, the *anatum* subspecies of the Peregrine Falcon was extirpated south of 60°N and east of the Rocky Mountains (Cade and Fyfe 1970) with the exception of unknown numbers in northern Alberta, near Ungava Bay, and along the Labrador coast. While peregrine populations increased in some parts of the eastern and western United States, the recovery in Canada has been slower (White, Fyfe and Lemon 1990; Murphy 1990). In 1970, in eastern North America, no known resident breeding populations existed south of the boreal forest (Cade and Fyfe 1970). The reestablishment of the peregrine therefore depended upon the release of captive raised falcons (Cade et al. 1988).

Since 1975, government and non-government agencies released young *anatum* falcons into southern Canada using hacking and fostering techniques (Fyfe 1987, 1988). The goal of these releases is to establish self-sustaining populations of Peregrine Falcons in southern Canada east of the Rockies. The *Anatum* Peregrine Falcon Recovery Plan (Erickson et al. 1988) established nine management zones in the *anatum* range based on political and ecological boundaries (See Figure 1 *in* Murphy 1990). The objectives of the recovery program are to establish a minimum of 10 pairs per zone by 1992 and to have natural production of 15 young per zone as a five year average by 1997.

This plan also discusses the factors that limit the recovery of the *anatum* Peregrine Falcon in southern Canada and recommends a series of management actions in priority that are required to successfully recover these populations (Erickson et al. 1988). The release program is a priority 2 activity after priority 1 activities of monitoring the populations, protecting the populations from pesticides and preserving the *anatum* gene pool. The gene pool is protected through the captive breeding facilities of the Canadian Wildlife Service, Wainwright; University of Saskatchewan, Saskatoon; and Macdonald College, McGill University, Montreal (Fyfe 1988). The other factors and recommended actions are: priority 2 — preserve habitat; priority 3 — protect peregrines from human disturbance and predation, and mitigate the impacts of disease and disaster; and priority 4 — increase public awareness and conduct research and development to improve management techniques.

TABLE 1. Summary of releases of captive-raised Peregrine Falcons in southern Canada

	1976	77	78	79	80	81	82	83	84	85	86	87	Total
southern Alberta	11	11	6	5	23	24	22	10	11	9	-	4	136
Saskatchewan	-	1	2	4	8	8	4	-	-	5	-	7	39
Manitoba	-	-	-	-	-	4	4	3	7	4	4	4	30
Ontario	-	4	4	8	15	16	12	3	18	14	12	24	130
Quebec	10	9	8	8	13	16	7	12	26	9	20	4	142
Maritimes	-	-	-	-	-	-	5	5	16	12	21	27	86
Total	21	25	20	25	59	68	54	33	78	53	57	70	563

This paper reviews the history of the releases and returns of captive raised Peregrine Falcons south of the boreal forest in Canada. The purpose is to evaluate some aspects of the release strategies and recommend alternatives to improve the success rate of the reintroductions. Not included here are foster releases in northern Alberta and Yukon Territories, as well as population surveys in Ungava Bay, the Labrador coast, Northwest Territories, Yukon Territories, and British Columbia. Foster releases occur when captive raised young are provided to territorial pairs of Peregrines to raise and fledge.

Results

Release Program

Between 1975 and 1987, 563 captive raised Peregrine Falcons were released in southern Canada (Table 1). The sex ratio of the released young was relatively equal (49% male: 51% female). The first Canadian release occurred in northern Alberta in 1975, followed in 1976 by releases at four sites in southern and central Alberta and two sites in Quebec. Since then peregrines have been released in all provinces except British Columbia, Prince Edward Island and Newfoundland. All captive raised young in Canada were banded with a red anodized aluminum band displaying a vertical alpha-numeric code and a standard US Fish and Wildlife Service band on the other leg.

There have been 110 releases. The largest releases were in Algonquin Provincial Park, Ontario (61 young in 9 years); Hull/Ottawa (55 young in 11 years); Montreal (52 young in 12 years); and Kananaskis Country, Alberta (49 young in 3 years). Birds were released in 24 areas with an average of 5.04 young per year per area. The number of young per release per year exceeded nine on 15 occasions.

In 10 Canadian cities over 11 years, 264 young were released. The average number of young per area per year was 4.7 and exceeded nine on only three occasions. All urban releases were from buildings.

Rural areas received 299 young for an average of 5.6 young per area per year. These releases exceeded nine young per year on nine occasions. All rural releases were from cliffs in varied habitats. The habitat around the Algonquin and Kananaskis releases is heavily forested. There have been 82 young released at six sites associated with prairie rivers and lakes of Alberta and Saskatchewan. Releases in Nova Scotia, New Brunswick and some in Quebec have been associated with marine shorelines.

Most Canadian releases (95%) used the hacking technique where humans provided the food for the young until the young attained independence. At a few release sites, returning but non breeding falcons helped to feed the introduced young, e.g., 1987 at Fundy National Park (see also Barclay and Cade 1983). At the Fundy site, the adult male also chased away Common Ravens (*Corvus corax*), potential predators that approached the release box (S. Hicks, personal communication). The extent of post-fledging training by these voluntary foster parents is unknown.

The remaining 5% of captive raised young were fostered to breeding peregrines to augment their brood, to replace broken or cracked eggs, or pairs suspected of having laid thin-shelled eggs in the past. Young were used to supplement production at urban releases in Calgary, Edmonton, and Montreal. None of these 13 young is known to have returned. Young were given to Prairie Falcon (*Falco mexicanus*) pairs at three sites in southern Alberta but this was discontinued due to concern about interspecific imprinting (Bird et al. 1975). Again none of these 13 young is known to have returned.

Peregrine Returns

The exact number of released birds seen in Canada at least one year after their release is difficult to determine. Some birds are recorded at or near a release site, but their band status, hence their identity, remains unknown. At other times a red band, indicating a Canadian captive raised and released bird, is noted but the alpha-numeric code is not observed. Only when the code or the U.S. Fish and Wildlife Service band number is reported does the exact identity of the falcon and its history become known.

TABLE 2. Distance (km) between release site and return sighting of captive raised and released Peregrine Falcons

	Paired Falcons		Single Falcons	
	N	Distance (± SD)	N	Distance (± SD)
Males	7	91 ± 121	15	33.3 ± 90
Females	10	283 ± 325	3	197.0 ± 170

The codes on the red bands were read on 35 different falcons during the breeding seasons. Approximately 11 other falcons were observed with red bands but the codes were not read. In addition at least three birds were reported with only U.S. FWS bands; one wore a black band; another had a green band; and at least seven were unbanded. Overall approximately 55 falcons were observed in the breeding season and apparently on territory, between 1978 and 1989. An additional 19 birds were reported but their band status was unknown. Some of these sightings could be repeats or falcons with bands that were observed in different years, thus obvious repeat records were removed from the totals presented here.

The average distance between release and return sites for all returns is 130.3 km (S.D. 217.5) but is further for females (263.1 km, S.D. 292.4, range 0 to 720) than for males (51.8 km, S.D. 101.8, range 0 to 300); however, this difference is not significant (Mann-Whitney U test, $P > 0.1$). Of the 35 identified falcons, 16 of 22 males and 5 of 13 females returned to their release site. The distance between release and return sites is significantly greater for pairs than for singles (204.1 km versus 60.6 km, Mann-Whitney U test, $P < 0.01$). Eighteen falcons, 15 males and three females, were observed as single birds. The remaining 17 were observed with potential mates during the breeding season (Table 2).

Hack sites and territories can be characterized as urban or rural. Most peregrines returned to a site similar to their release site (32 of 35, 91%). This rate is lower in the USA (Cade and Bird 1990). However, young released at rural sites returned at a lower rate than those from urban sites. Of the 35 identified falcons, 24 were released from urban sites representing 10% of releases at urban sites, while the other eleven (4%) were released from rural sites. These data could be biased since falcons that return to urban areas are presumably detected more easily. Five of the 11 rural releases were in the Bay of Fundy area where considerable effort was expended to locate territorial birds. At the two largest rural release sites, Algonquin Park and Kananaskis Country, falcons could nest undetected on many remote cliffs. Spring surveys are difficult in Algonquin because of late ice breakup (G. McKeating, personal communication). Alternately, many of the falcons that were released in forested areas may have died. Nevertheless, the fate of falcons released in forested areas remains unknown.

Eighteen falcons, 13 males and 5 females, were first observed at one year of age while 10, 4 males and 6 females, were first observed at two years of age (Table 3). The oldest first time observation is of a single six-year-old male during 1987 in Winnipeg which was not reported in 1988. All observed females appeared by their third year. The average age of first appearance of males is 1.8 years, while for females it is 1.9 (Table 3). Fifty percent of the falcons are seen for only one summer. Consequently the average age of last return is only slightly higher than that of first sightings (Table 3). There is a slight tendency for paired males to live longer on average than other categories, although two females were seven and eight years old in 1988.

In 1980, peregrine pairs established territories and bred in southern Quebec (Bird and Aubry 1982) and in Edmonton. These were the first recorded nesting by captive raised and hack released young in Canada. Since then, the number of known territorial pairs in southern Canada has increased to 12 in 1988 (Table 4). Quebec has the most pairs and singles. Recent releases in the Maritimes resulted in pairs but no young by 1988. At least six single birds were recorded in and near potential breeding sites in 1988.

In 1980, a Quebec pair, both captive raised and released falcons, produced the first two young. The

TABLE 3. Age of returning Peregrine Falcons at first and last sighting

		Age of return sighting (years)								
		1	2	3	4	5	6	7	8	mean S.D.
Males:	first	13	4	3	1	0	1	0	0	1.78 ± 1.35
	last	7	5	1	1	2	2	0	0	2.47 ± 1.48
	1988*	0	1	0	2	0	0	0	1	
Females:	first	5	6	2	0	0	0	0	0	1.88 ± 1.13
	last	2	3	3	1	0	0	0	0	2.20 ± 1.43
	1988	1	0	0	1	0	0	1	1	

*If the last sighting was 1988, it is reported separately since these falcons may still be alive.

TABLE 4. Number of territorial pairs and single Peregrine Falcons in 3 management zones as outlined in the *Anatum* Peregrine Falcon Recovery Plan

		1978	79	80	81	82	83	84	85	86	87	88
Zone 1												
southern	pair	1	2					2	1	3	3	6
Quebec	single F							1			1	1
	unidentified								3		1	
Maritimes	pair										1	
	single M								1	2	1	1
	F								1	2		1
	unidentified							1				1
Zone 2												
southern	pair						1					2
Ontario	single M					1	1	1	2	2	1	1
	F									1	2[2]	2
Zone 3												
southern	pair				1	1	2	2	2	2	2	1
Alberta	single M	1	2	1	5	2	1				1	2
	F			1						1	1	1
Saskatchewan	pair											1[1]
	single M								1	2	1	1
Manitoba	pair											2
	single M										1	1
Total birds		3	6	2	7	5	8	11	14	21	22	35

[1]Pair includes a falconry trained female that was introduced to a territorial male.
[2]Females bred in the U.S. but were released in Ontario.

number of young produced in subsequent years is difficult to calculate since eggs and captive raised young have been switched at some sites and usually only easily accessible urban sites were checked. Since 1980 12 wild young plus 14 captive raised young fledged in Edmonton and Calgary, while 27 young fledged in Quebec including at least 11 in 1988.

Discussion

The above returns pose several questions that require consideration in an evaluation of the success of the recovery effort. What are the origins of these returning birds? How many captive raised young were observed after at least one year? What characteristics of these releases might affect the chances of the falcons returning to Canada? In the conclusion we offer suggestions for future release efforts.

Most territorial falcons (79%) originated from Canadian hack releases. One female, wearing a black band in Winnipeg during 1988, was from a 1987 Minneapolis release (Tordoff and Redig 1988; R. Nero, personal communication). Another female, that wore a blue band and bred in southern Quebec in 1980 was released in the north-eastern U.S. (Bird and Aubry 1982). Three falcons, wearing only U.S. FWS bands, were reported in southern Ontario and Quebec. While they were most likely banded as wild young in the United States, they could have been banded as passage birds at trapping stations.

The distance between the release and return sites of falcons in Canada is comparable to those in the USA. Peregrines in the upper mid-western USA dispersed on average 117 km (Tordoff and Redig 1988) compared to 130 km in Canada with females dispersing longer distances and more males returning to or near their release site. Likewise in the Rocky Mountains in the USA, females dispersed 279 km on average and males 68 km, similar to the Canadian distances of 263 km and 52 km respectively (Burnham et al. 1988). Since the dispersal distance is large, particularly for females, the current emphasis for releases in Canada at potentially attractive nest sites may be unwarranted, especially if the site is inaccessible to humans or more costly to use than others. The abundance of single territorial males provides opportunities to release females that have been retrapped and held over the winter as was done in Saskatoon in 1988 (L. Oliphant, personal communication). This "manufactured" pair successfully fledged fostered, captive raised young but none of their own.

Six of seven unbanded peregrines, that were reported in southeastern Canada, were paired. The first sighting, a male, was paired with a red-banded female at Ste Foy, Quebec, in 1986. The second male appeared in 1987 at Pont Pierre Laporte,

Quebec City, paired with a female that had been released in Toronto in 1984. The remaining five sightings occurred in 1988: a male in Montreal paired with a female wearing only an aluminum band; a male in Winnipeg paired with a Minneapolis released female; a pair in southern Ontario; and a female that overwintered in Ottawa.

Unbanded falcons almost certainly are wild bred since all captive raised falcons released in Canada wear two bands that are unlikely to have been removed or lost. However, the origin of these unbanded falcons remains open to conjecture. They could be from wild sites in the USA as not all wild raised young were banded. However, five of seven unbanded falcons were males which tend to disperse short distances, i.e., an average of 56 km. This does present the possibility that some of these birds were raised at wild sites in Canada. Some of these sites are known but few young have been banded because of concern about disturbing the parents and young, the lack of qualified climbing banders, and the inaccessibility of some cliff sites, e.g., Saguenay River in Quebec. The first wild-raised Canadian falcons from captive raised and released falcons were two young at a southern Quebec site in 1980 (Bird and Aubry 1982). Thus these unbanded peregrines could be wild raised offspring of captive raised Canadian released falcons.

The third possible source of these unbanded falcons is from unknown wild Canadian nests. Since the releases in Algonquin, Hull and Montreal began in 1976 and 1977, enough time passed for pairs to form and breed in the wild. This possibility implies the need to rigorously check remote cliffs in southern and central Ontario and Quebec in the five-year survey planned for 1990.

Overall, relatively few Peregrine Falcons returned or were sighted in the breeding season. Of the 58 falcons with known band status, 46 (79%) had red bands and were from Canadian releases. If the same percent of unknown birds, 14 of 18, are also from Canadian releases, then 60 falcons (10.6%) returned from the 563 young released in southern Canada.

In the Rocky Mountains of the USA, 673 young were released between 1976 and 1985 with a maximum of 20 returning birds in 1985 (Burnham et al. 1988), lower than the Canadian returns from slightly fewer releases. On the other hand, in the eastern USA between 1975 and 1981, 52 falcons (14.7%) returned from 353 released (Barclay and Cade 1983). Even higher are the return rates of 20% in all habitats between 1976 and 1979 and of 39% at coastal salt marshes in New Jersey (Barclay 1980).

The return rate varies with location. Of the larger releases, the return rates were lowest at Kananaskis Country, Alberta and Algonquin Provincial Park, Ontario. However, young released at Algonquin could breed undetected in the remote forest lands of this region. This possibility is supported by the sighting of unbanded falcons in southern Ontario in 1988 and southern Quebec between 1986 and 1988. Three males returned to Kananaskis Country but no known pairs have formed. Nelson (1987:5) used survival rates of peregrines in Great Britain to argue that some of these released young should have survived and suggests "that the Peregrine recovery in Alberta is slowly occurring (unseen) in the eastern slopes of the Rocky Mountains . . .". He concluded that the major problem is the lack of effort invested to search for nesting peregrines in remote areas of the Rockies.

Peregrine Falcons are most numerous in areas with high densities of suitable prey (Newton 1979; Ratcliffe 1980). High numbers of seabirds on coastal areas support breeding pairs (Nelson and Myres 1975; Ratcliffe 1980). Likewise tundra peregrines prey upon small mammals in arctic areas, especially when prey are in cyclical high numbers (Court et al. 1988). The abundance of available prey in forested areas as compared to open country habitats such as marshes affects the development of the peregrine's hunting behavior (Sherrod 1982). Cade and Bird (1990) reported that the majority of urban nest sites in eastern North America in 1980 were within 800 m of water. Barclay (1980:83) concluded "the local food resource may be one of the major determinants of the suitability of artificial release sites".

The characteristics of the release site may be critical to the success of the recovery effort. Overall, urban releases resulted in proportionately more returns than rural releases. However, rural release sites around the Bay of Fundy with its tidal areas have had a higher return rate than other rural areas, consistent with the results from coastal New Jersey (Barclay 1980). Future release sites should have adequate prey to support inexperienced young Peregrine Falcons and returning birds.

The recovery effort to reintroduce *anatum* Peregrine Falcons into southern Canada resulted in the release of 563 captive raised young between 1975 and 1988, and in 1988 12 pairs existed where one occurred in 1970. However, the low return rate (10.6%) indicates some room for improvement in the release effort. We offer the following suggestions:

(1) Larger releases, 20 to 30 young per area per year, will increase the likelihood of pairs becoming established; (2) the available prey base at all release sites must be abundant to increase the initial survival of fledgling falcons; (3) monitoring of potential breeding

sites must be adequate to detect territorial pairs; (4) once territorial pairs are located, their band status should be determined to establish their origin, but only without undue disturbance; and (5) where lone territorial males occur, falconry trained females could be released to establish pairs and captive raised young introduced if the pair fails to breed.

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Peregrine Falcons, *Falco peregrinus*, Nesting in an Urban Environment: A Review

TOM J. CADE[1] and DAVID M. BIRD

[1]The Peregrine Fund, World Center for Birds of Prey, 5666 West Flying Hawk Lane, Boise, Idaho 83709
Macdonald Raptor Research Centre of McGill University, 21,111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0

Cade, Tom J., and David M. Bird. 1990. Peregrine falcons, *Falco peregrinus*, nesting in an urban environment: a review. Canadian Field-Naturalist 104(2): 209–218.

In 1988, 30 to 32 pairs of the Peregrine Falcon (*Falco peregrinus*) were present in at least 24 cities and towns in North America. Of 24 nesting pairs, only 3 failed and the remaining 21 pairs raised 42 to 45 fledglings (including some fostered young). The production of young per successful pair in 1988 was 2.45 for urban sites vs. 2.51 for rural sites. From 1975 to 1988, 89 percent of 184 peregrines released at Canadian urban sites survived to the flying stage, and in the United States 83 percent of 52 urban-released (hacked) peregrines survived to independence. Bridge sites were associated with a low fledging success. Of 16 urban breeders of known origin, 7 came from rural sites. The height of buildings used ranged from 14 to 50 floors; east-facing sites were most preferred. Prey items were quite diverse with Rock Doves (*Columba livia*) being most common. The most significant hazards, especially to fledglings, were premature fledging, collisions, and poisoning from pest control programs.

En 1988, on a dénombré de 30 à 32 couples de Faucons pèlerins (*Falco peregrinus*) dans au moins 24 villes et villages en Amérique du nord. Sur un total de 24 couples reproducteurs, 21 couples ont élevé de 42 à 45 oisillons (dont quelques-uns provenaient de centres de reproduction) et trois couples seulement ont échoué. En 1988, le nombre moyen de jeunes par couple couveur était de 2,45 pour les sites urbains, par comparaison avec 2,51 pour les sites ruraux. De 1975 à 1988, 89% des 184 Faucons pèlerins relâchés aux sites urbains canadiens ont survécu jusqu'au stade de l'envol, et aux États-Unis 83% des 52 Faucons pèlerins relâchés aux sites urbaines ont survécu jusqu'au stude de l'indépendance. Les lâchers effectués à partir des ponts ont connu un taux faible de succès. Des 16 Faucons pèlerins reproducteurs dont l'origine était connue, sept provenaient de sites ruraux. La hauteur des immeubles utilisés allait de 14 à 50 étages et les sites qui donnaient sur le côté est étaient les plus favorisés. Tout en étant assez diverses, les proies les plus communes étaient les pigeons bisets (*Columbia livia*). Les risques les plus importants, particulièrement en ce qui concerne les oisillons, étaient l'envol prématuré, les collisions et l'empoisonnement causé par les programmes de lutte contre les cuseaux nuisibles.

Key Words: Peregrine Falcon, *Falco peregrinus*, breeding, reproduction, release, urban, cities, buildings.

The Peregrine Falcon (*Falco peregrinus*) seldom nested successfully in North American cities in the era before the pesticides-induced population crash of the 1950s. J. J. Hickey and D. W. Anderson attributed this failure "to a lack of the proper nesting substrate for their eggs, to the birds' noisy intolerance of intrusion when they have young, and to the absence of terrain in which the young can safely make their first flight" (Hickey 1969). There were several notable attempts in former times: twice unsuccessfully owing to human interference on the St. Regis Hotel in Manhattan in the 1940s (Penny 1981), successfully on the old City Hall tower of Philadelphia in 1946 and lower down in 1949 (Groskin 1947, 1952), successfully on a church steeple in Harrisburg, Pennsylvania (Groskin 1952), and most successfully of all on the Sun Life Assurance building in Montreal, Quebec, where the same female nested continually from 1940 to 1952 and raised 22 young from 3 different males (Hall 1955). Several less certain cases have been rumored for the Los Angeles basin in the 1940s. Peregrines were purported to hunt Rock Doves (*Columba livia*) in Baltimore in 1940 and perhaps as early as 1930 (K. Carnie, personal communication).

The widespread extirpation of Peregrine Falcons owing to the effects of DDT and dieldrin in the 1950s prevented any further exploration of urban habitats by falcons dispersing from the countryside in search of new territories.

Four decades later, in 1988, the situation is very different, as 30 to 32 pairs of peregrines were present in at least 24 cities and towns spread across the entire continent in both Canada and the United States, not to mention the frequent occurrence of unmated falcons in these and other urban locales (Tables 1 and 2). This situation is not unique to North America, as peregrines have also taken up residence on buildings in Europe (Mebs 1988).

Origins of Urban-nesting Peregrines

This contemporary, urban population of peregrines is largely composed of captively reared and released falcons from various restocking projects in Canada and the United States.

TABLE 1. Urban peregrines breeding in the United States and Canada, 1988.

Location	Site	Remarks, Breeding, etc.	No. of Young fledged	Source
Edmonton, Alberta	Alberta Govn't Telephone Bldg., 13th floor	Female laid 3 eggs w/o mate; 2 males came; laid 2 more infertile eggs; males left; laid 6 more eggs	0	J. Folinsbee
Calgary, Alberta	Alberta Govn't Telephone Bldg.; 13th floor	Pair adults; 5 eggs, none hatched, reared 3 fostered young	3*	T. Nette
Winnipeg, Manitoba	2 different bldg. sites	2 pairs in city, no nest found	—	R. Nero
Saskatoon, Saskatchewan	hack box on Bessborough Hotel	Pair formed by falconry-trained birds, male established 1st, then female released; no nest but accepted 3 fostered young	3*	L. Oliphant
Arnprior, Ontario	church steeple	Pair nested in 1987, female and 2 fledged young in 1988 — probably from eyrie across river	2*	J. Carreiro
Ottawa, Ontario	various bldgs.	Several adults reported — no nesting	—	J. Carreiro
Quebec City, Quebec	Pierre Laporte Bridge nest box	Female laid 9 eggs in 9 places in 1987; laid in nest box in 1988	1+?	P. Laporte
Montreal, Quebec	Old Royal Bank Bldg.; nest boxes on 3′ wide ledge around bldg.	New pair in 1988, 4 eggs, disturbed by bldg. cleaning operation; 2 hatched in lab incubator, returned, 2 fledged, 1 hit window	1	D. Bird
Boston, Massachusetts	Custom House, nest box	Prospecting earlier in the season; moved to Custom House	2	T. French
Springfield, Massachusetts	Monarch Place Bldg.	Canadian female and male with double black band; no nesting	—	T. French
New York, New York (1)	Cornell Univ. Med. School high window ledge, nest box	Site occupied for first time in 1988	2	M. Gilroy
New York, New York (2)	Throg's Neck Bridge, nest box	Eggs removed and hatched in laboratory, no recycle, 1 young fostered	1*	M. Gilroy
New York, New York (3)	Verrazano Narrows Bridge hole under roadway	Pair failed on eggs	0	M. Gilroy
New York, New York (4)	Tappan Zee Bridge nest box	3 young, one flew into water and rescued by boatman, but apparently only 1 fledged	1	M. Gilroy
New York, New York (5)	Near World Trade Center	Persistent sightings of adults flying around, but no nest reported	—	M. Gilroy
Philadelphia, Pennsylvania (1)	Commodore Barry Bridge	Renest PA side after eggs removed from nest on NJ end, 1 yg. picked up, 2 others seen	1-3?	M. Gilroy
Philadelphia, Pennsylvania (2)	Girard Point Bridge hole under roadway	First found in 1988 but sign indicates prior use	2	M. Gilroy
Atlantic City, New Jersey	Golden Nugget Casino penthouse ledge, nest box	Pair hatched 2, 1 died shortly after hatching 1 young fostered from Ocean Gate	2*	M. Gilroy
Baltimore, Maryland (1)	USF&G Bldg., window ledge 33rd floor, nest box	Same pair as last year, Beauregard & Blythe	2	M. Gilroy
Baltimore, Maryland (2)	Francis Scott Key Bridge	Pair present for several years but always fail until this year	1	M. Gilroy
Norfolk, Virginia	downtown skyscraper	Two birds in early spring, pair?, then only occasionally one — no nest	—	M. Byrd
Toledo, Ohio	Commodore Perry Motor Inn (closed), small penthouse ledge on 16th floor	Male adult, female immature, red bands on both (Canadian)	2	R. Smith
Detroit, Michigan	Guardian Building	Pair of immature falcons — no nest, harassed released young	—	G. Septon
Chicago, Illinois	Window ledge high up on skyscraper, 34th floor	Pair present last year — adult this year	2	M. Spreyer
Milwaukee, Wisconsin	Wisconsin State Bank Building, hack box	Both mates immature, 2 young fledged and 2 fostered, but male attacked 2 in air	2	G. Septon
Minneapolis, Minnesota	Multi-Foods Building, nest box on window ledge	New male, young moved to roof after hatching 3 plus 1 fostered	4*	H. Tordoff

TABLE 1. *Concluded*

Location	Site	Remarks, Breeding, etc.	No. of Young fledged	Source
St. Paul, Minnesota	30-storey bldg., nest box on window ledge	4 young moved to roof after hatching, 2 poisoned	2	H. Tordoff
Salt Lake City, Utah	Nest Box on Hotel Utah window ledge	Pair present for 3rd year	2	W. Heinrich
San Francisco, California	Oakland Bay Bridge, midspan	2 pairs coalesced into one, 1 young fledged into water, rescued and returned	1	B. Walton
Los Angeles, California (1)	Union Bank Bldg., next box on high ledge behind sign	Eggs taken for lab incubation, 1 young fostered later	1	B. Walton
Los Angeles, California (2)	Calif. Fed. Sav. & Loan Bldg., box on window ledge	Eggs taken for lab incubation, no young fostered	0	B. Walton
Long Beach, California	Vincent Thomas Bridge	Pair present for several years, no young fostered	—	B. Walton

*Fostered young included.
Summary: (a) 30-32 territorial pairs.
(b) 24 nesting pairs.
(c) 21 successful pairs, including those raising fostered young.
(d) 42-45 young fledged, including 13 fostered and 2 extraneous.
Minimum authocthonous productivity = 1.2 young/nesting pair.
Maximum overall productivity = 1.9 young/nesting pair.

While many urban-nesting Peregrines were originally released in cities, some were not. For example, the 2 falcons that bred in Montreal in 1984 had been released from cliff sites in Vermont and New York. Furthermore, none of the 4 pairs nesting in New York City include birds released there in earlier years. Of 9 birds released in Los Angeles in recent years, 5 became breeders at 2 nest sites in that city (B. Walton, personal communication), but several subsequent replacements came from the countryside.

The majority of 46 breeding peregrines in the eastern United States returned to the same type of site from which they fledged (Table 3). Of 16 urban breeders, 7 originated from rural sites, whereas the tower and cliff breeders were derived only from birds released at those types of sites. Twenty-nine of 32 peregrines released in Canada returned to a site similar to their release site (Holroyd and Banasch, this issue).

It is also a common misconception that peregrines are only nesting in cities where releases have occurred. Nine of the 24 cities listed in Table 1 that were home to pairs of falcons in 1988 have never had peregrines released in them. As their name suggests, these falcons are great wanderers and birds released in Toronto have ended up in Boston and Springfield. Montreal birds have dispersed to Winnipeg and Detroit, and a Detroit bird flew to Toronto, to name but a few cases.

Although wild peregrines have nested from time to time on old European castles, cathedrals or other such structures (Mebs 1969; Saar 1988), it does appear that these captively reared and released peregrines have a stronger proclivity than wild birds to be attracted to man-made structures as nest sites and to enter urban environments. In addition to tall buildings, they have set up housekeeping on bridges, towers, the superstructure of a decommissioned liberty ship, and in an old Raven's (*Corvus corax*) nest on top of a window-mounted air conditioner under the eaves of an abandoned hunting lodge.

These reintroduced falcons may exhibit such plastic behavior because they are less afraid of human beings and their artifacts than wild birds are and because they also have a wider variety of early experiences with different, usually artificial, environmental situations than wild young do. Typically they hatch in incubators, are hand fed in the laboratory for a few days, than parent reared in a cage, fed again by humans in a hack box and during the fledgling period — all before they become independent, "wild" birds in the out-of-doors.

Urban Releases of Peregrines

Biologists first became intrigued by the idea of releasing peregrines in cities because of problems

TABLE 2. Growth of the urban population of Peregrine Falcons in the eastern United States from 1980 to 1988.

Year	Breeding Attempts	Productive Pairs	Young Produced	Young per Attempt	Young per Successful Attempt
1980	1	1	2	2.0	2.0
1983	3	2	5	1.7	2.5
1984	5	4	12	2.4	3.0
1985	5	3	11	2.2	3.7
1986	6	5	11	1.8	2.2
1987	11	6	14	1.3	2.3
1988	10	8	16	1.6	2.0
Total	41	29	71	1.7	2.5

Data compiled by M. Gilroy.

encountered in the countryside with natural predators of young falcons. It seemed obvious that metropolitan environments, at least at the skyscraper level, would be free of Raccoons (*Procyon lotor*), Red Foxes (*Vulpes vulpes*), and Great Horned Owls (*Bubo virginianus*), although an owl showed up in broad daylight on a high building to discourage a nesting attempt in Montreal in 1982! Also, cities abound in feral pigeons (generally regarded as the falcons' favorite food), Starlings (*Sturnus vulgaris*), and other suitable prey. Moreover, tall buildings mimic cliffs, and all that is needed to turn many skyscrapers into suitable eyries is to provide a box with sand and gravel to give the falcons an appropriate substrate in which to make their nest scrape, as was so successfully demonstrated by the Sun Life falcons in Montreal (Hall 1955). Yet another attractive feature is proximity to water, i.e. rivers, lakes and oceans. Of 19 urban nesting sites sampled from Table 1, 12 were within 400 meters of water, 4 within 800 meters, and only 2 were not near any sizeable body of water. Presumably, the falcons associate such bodies of water with an abundance of waterbirds and perhaps with routes for migratory species. They also provide open hunting spaces for the falcons (Cade 1960).

In cooperation with Dr. Heinz Meng, The Peregrine Fund carried out the first experimental release from a building in 1974, from the top of the Faculty Tower on the campus of the State University College at New Paltz, New York. The project has been described in detail by Kaufman and Meng (1975).

Serious work on releasing peregrines from tall buildings began in 1976 when the Canadian Wildlife Service released birds in Edmonton and Montreal (Holroyd and Banasch, this issue). This program was later expanded to other Canadian cities, i.e. Calgary, Toronto, Ottawa-Hull, Winnipeg, Saskatoon, Quebec City, Ste. Catharines, and Brockville. In 1979, The Peregrine Fund released young over a 2-year period from the roof of the Interior Department Building and from the old Smithsonian "castle" in Washington, D.C. In 1980 they began releasing in Manhattan from the roof of the Metropolitan Life Building and, later, from the headquarters of Consolidated Edison Company of New York.

Other U.S. urban release sites have included Portland (Maine), Norfolk, Philadelphia, Boston, Albany, Chicago, St. Louis, Detroit, Milwaukee, Minneapolis-St. Paul, Denver, Boise, and Los Angeles.

Hazards to City-nesting Peregrines

While all of the postulated advantages of urban environments proved true, there are also *disadvantages* mainly associated with life-threatening circumstances when the young falcons are developing their ability to fly.

Deaths and serious injuries result when birds fly into plate glass windows and even into the sides of concrete buildings. Tinted and/or mirrored glass buildings have proven particularly troublesome. Observers at 14 of 19 urban sites surveyed from Table 1 cited collisions with this type of building as their major concern. Often they result from some combination of inexperienced flight, strong and sometimes unexpected wind shears, and being startled either purposefully or inadvertently by

TABLE 3. Origins for known breeders in eastern United States Peregrine Falcon population.

Breeding Site	Origin (hack or hatch site)			
	Urban	Tower	Cliff	Total
Urban	9	3	4	16
Tower	0	23	0	23
Cliff	0	0	7	7
Total	9	26	11	46

Data compiled by M. Gilroy.

human intrusion. Sudden gusts of wind have been known to sweep young falcons off nest ledges (J. Jennings, unpublished report). Paul Young (unpublished report) noted that some fledgling peregrines lose altitude easily, i.e. 6 to 7 building floors per 10 sec of flight. He had to return several young birds to their nest site after grounding.

Young peregrines have also been known to collide with wires and other artificial structures. Still other fledglings have lost their balance and fallen into open chimneys, air vents and even small courtyards with vertical walls, in which they became entrapped, or became entangled in fish line dangling from the girder of a building under construction.

Several peregrines attracted to the open space and birdlife at nearby airports have collided with aircraft landing or taking off. One building used by peregrines had a heliport. While the loud noise and vibration seldom bothered the falcons, the female occasionally chased the departing helicopter for 30 metres or so (P. Young, unpublished report).

Perhaps the most serious problem facing young peregrines fledging in urban environments is their tendency to flutter or "helicopter" to street level (sometimes earlier than normal), usually uninjured. This type of hazard occurs most often at buildings with sheer drop-offs to ground level, i.e. no terracing. Of 16 buildings housing peregrines in 1988 (Table 1), 12 had such drop-offs.

Once at the street level, the falcons are at risk from heavy traffic, dogs, people, and starvation. Often the adult birds are either reluctant to bring food down to grounded fledglings or they cannot locate their young due to high noise levels and numerous nooks and crannies, e.g. parked vehicles, where the frightened birds can hide from view.

Heavy traffic can be a problem for both young and adult birds. Falcons attempting to retrieve kills near busy freeways are at risk (P. Young, unpublished report). Young birds fluttering into heavy traffic have led to the appointment of traffic patrolmen to protect human rescuers, as well as posted warning signs in Salt Lake City in 1986 (W. Heinrich, personal communication).

Bridges are particularly noteworthy for traffic fatalities among falcons. One of the Baltimore males was killed by a vehicle on the Francis Scott Key Bridge in Baltimore. Bridges have other problems, including a low fledging success rate. Of 11 bridge sites in North America in 1988, only 5 were successful in producing a total of 6 young (Table 4). Young birds often fledge into the water and may drown if not rescued by human observers. Other sites offer easy access to children with BB guns. Bridges with a lot of supporting structure, i.e. towers, piers, anchors and framework, offer more landing and branching opportunities for both fledgling and adult birds as opposed to simple arching bridges.

TABLE 4. Reproductive success of Peregrine Falcons nesting on bridges in North America in 1988.

Location	No. Attempts	No. Productive	No. Young
Walt Whitman Bridge, Philadelphia	1	0	0
Throgs Neck Bridge, New York	1	0	1*
Commodore Barry Bridge, Philadelphia	2	1	1
Betsy Ross Bridge, Philadelphia	1	0	0
Delaware Memorial Bridge West	1	0	0
Verrazano Narrows Bridge, New York	1	0	0
Girard Point Bridge, Philadelphia	1	1	2
Francis Scott Key Bridge, Baltimore	1 or 2?	1	1
Oakland Bay Bridge, California	1	1	1
Vincent Thomas Bridge, Long Beach, California	1	0	0
Pierre Laporte Bridge, Quebec City	1	1	1+

*1 young fostered.
Data compiled by M. Gilroy.

Toxicological Hazards

Several peregrines in different cities, 3 of them in Baltimore, have died from eating strychnine-poisoned pigeons. Little is known of secondary poisoning effects from avitrol, particularly when used at higher than normal concentrations. Some suspect lead poisoning as a problem caused by pigeons feeding at street level. Higher lead concentrations have been reported in urban birds (Tansy and Roth 1970). More recently, blood samples from 20 adult Merlins (*F. columbarius*) feeding on House Sparrows (*Passer domesticus*) revealed potential lead problems (L. Oliphant, personal communication). DDE and PCB levels in fledgling peregrines killed in collisions in Canadian cities in 1988 were deemed insignificant (Peakall et al., this issue). A more recent concern is the organophosphate, fenthion. There have been suspected cases of fenthion poisonings in Saskatoon Merlins. In a controlled laboratory study in 1988, K. Hunt, D. Bird and P. Mineau (unpublished data) fed House Sparrows exposed to fenthion to American Kestrels (*F. sparverius*) and all 14 falcons subsequently died.

TABLE 5. Comparative production in urban vs. non-urban pairs of Peregrine Falcons breeding in the eastern United States, 1977-1988.

	Urban	Non-Urban	Total
Breeding Attempts	41	134	175
Productive Pairs	29	103	132
Young Produced	71	258	329
Young per Attempt	1.7	1.9	1.9
Young per Successful Attempt	2.5	2.5	2.5

Data compiled by M. Gilroy.

Other concerns include peregrines drinking or bathing in contaminated water collected in cooling units atop older buildings, or catching prey in sewage lagoons attracting myriad numbers of shorebirds. The effects of noise pollution from machinery like compressors and blowing fans is not known. Even human activity behind windows can disturb falcons on a ledge. For example, one pair which fledged 2 young in Los Angeles was composed of a male which often dozed only a meter away from workers in their offices. The female, on the other hand, vocalized at any excessive movement in the office and constantly slammed her feet into the window when food was brought to the young, whether people were present or not (P. Young, unpublished report). In contrast, another Los Angeles female was calm and approachable enough to allow Brian Walton to not only switch her eggs while she was sitting on them, but, on another occasion, even grab her to read the band numbers. Video cameras located less than five meters from the nest site have not disrupted nesting activities.

Despite the varied and sometimes bizarre accidents that befall city-released peregrines, the success rate overall compares favorably with the results of release from towers in open country and from natural sites on cliffs. Jack Barclay of The Peregrine Fund analyzed the results of releasing peregrines in the eastern United States from 1975 to 1981 and found that 83 percent of 52 falcons released at urban sites survived to independence. This figure compares well to birds released from towers (79 percent of 178) and to those released from cliffs (63 percent of 123). In more recent years, since moving release sites out of Great Horned Owl country, the latter figure has risen to 80-85 percent and higher. Canadian releases between 1976 and 1985 were composed of 234 Peregrines in rural sites and 184 in urban ones with 88% and 89% of birds surviving to the flying stage, respectively (Fyfe 1988). Holroyd and Banasch (this issue) reported that Canadian-released peregrines released at urban sites were more likely to return to nest than ones hacked from rural sites; however, they conceded that birds returning to urban sites may be easier to detect.

Releases in cities have generally been successful, and they have contributed significantly to the establishment of an urban-nesting population, which is obviously expanding in size and distribution (Table 2).

Reproductive Success

In 1988, out of 24 nesting pairs, there were only 3 failures (one of them fledged fostered young), and the 21 successful pairs (including those with fostered young) raised 42 to 45 fledglings (Table 1). From 1980 to 1988 in the eastern United States, 71 percent of 41 nesting attempts in cities succeeded in producing an average of 1.7 young per attempt; at the same time, 77 percent of 134 attempts at non-urban sites produced an average of 1.9 young per attempt (Table 5). In short, the rate of reproduction in the urban birds compares well to the performance of healthy, expanding populations nesting not only in the eastern United States, but also in Colorado (Enderson et al.), Scotland (Newton and Mearns), the French Jura Mountains (Monneret), and other reports in Cade et al. (1988).

Other Concerns

How many pairs of peregrines a given city or town can hold will, of course, depend on the its size and number of potential nest sites, e.g. buildings, bridges, etc. In Los Angelas, one pair nested on the Union Bank with another pair on the Cal Fed Building only 9 kilometres away. Currently in 1989, there are 8 territorial pairs in the greater New York City region, and 2 nesting along the East River are only 3 kilometres apart.

Releasing young peregrines in the vicinity of established nesting pairs or a single territorial male has often led to disaster, e.g. direct killing by adults or restricted access to food at hack sites leading to starvation. In some cases, a single adult male or a pair can be induced to become foster parents for young in hack boxes by playing taped recordings of begging calls (L. Oliphant, personal communication). On the other hand, a male in Milwaukee in 1988 killed 2 of his foster young after they fledged.

Physical Features of Nest Sites

Not all cities have environmental features that favor a high likelihood of success in either releasing birds or attracting a nesting pair. While a few pairs are nesting on fairly low buildings, including ones standing alone in smaller cities, the best results in releasing young (hacking) peregrines have been achieved, and most nesting pairs have been established, in cities with several tall buildings.

In a sample of 18 buildings chosen by nesting Peregrines in Table 1, 3 are the tallest in the city, and 11 are among the tallest. With one exception, all buildings were located only 1 block from other tall skyscrapers, and the proximity to water was noted earlier.

Obviously, tall buildings are more visible to peregrines. Moreover, it is quite useful to have one or more surrounding buildings around the same height or slightly higher than the building used by the falcons or for release (hacking). It not only serves to give the fledged young a better view of the release box or nest, but can also act as an observation post for wardens.

In a sample from Table 1, the average height on 13 buildings where peregrines attempted to nest was 30 floors, ranging from 14 to 50 stories. The birds nested on average on the top 10% of the building, i.e. the 13th to the 50th floor. Five of 13 pairs nested on the roof, while one pair on Hotel Utah in Salt Lake City raised 2 young in a nest tray on the 9th floor.

Recommendations for Urban Releases

When selecting sites for either release (hack) boxes or nest trays, it is advisable to stay away from rooftops or ledges that have dangerous machinery, open water air conditioning units, large fans, open shafts or chimneys, live wires, soft tar that might accumulate on their talons, etc. Certainly, restricting access to roof tops as opposed to ledges is inherently more difficult because of maintenance requirements.

The architecture of old buildings like the Sun Life Assurance Building in Montreal provides numerous window ledges, cornices, or other convenient perches and potential nest sites at various levels. Descriptions of the physical features were obtained for as many of the building sites as possible listed in Table 1. One-half of 16 buildings used offered almost unlimited sites, 5 offered 2 to 4 sites, while 3 had only 1 site. The fact that most buildings must be provided with gravel-filled nest trays to allow the falcons to make a nest begs the question as to how many trays should be provided, i.e. just one or several. Providing 4 sites on a Montreal building resulted in a clutch being split between 2 trays (D. Bird, unpublished data). According to T. French (personal communication), a pair in Boston laid eggs in 4 different sites over two years. Even more prominent is the case of the peregrines laying 9 eggs in 9 different sites on a bridge in Quebec in 1988 (P. Laporte, unpublished data).

Older style buildings with several small roof tops are more likely to offer a roof site without machinery and/or heavy maintenance activity. Surprisingly though, but perhaps due to their greater availability, 13 "new" buildings as opposed to 7 "old" ones, i.e. over 20 years old, were chosen by nesting peregrines. As stated beforehand, 12 of 16 buildings chosen had sheer drop-offs to street level.

Ledge widths on 11 buildings chosen by peregrines ranged from a half-meter to 2 meters with a meter being most common.

Despite the fact that 5 sites were biased because the nest boxes were deliberately placed facing east, that direction was most often chosen by nesting peregrines (10 sites). Other favoured directions were south (4), south-east (3), north (2), north-east (2), and 1 each for west, south-west and north-west. Presumably, a nest site protected from prevailing winds and excessive direct sunlight is preferred by peregrines.

Clearly, managers fo both release sites and breeding pairs in urban environments can do much to minimize injury and mortality and enhance reproductive success. Buildings should be chosen where sheer, transparent glass facings on adjacent buildings are few or absent. There should also be few smoke stacks, air vents, air-conditioning units, or other mechanical contraptions which are likely to endanger recently fledged young, and all such hazards in the immediate environs should be screened from entry by peregrines. In Detroit, chimneys were capped and in Chicago, cooling units were covered with screening (P. Redig, personal communication) because one bird had previously drowned in such a unit. Ideally, there should be no major construction projects nearby. Discussions with pest control companies to curtail strychnine poisoning programs have been fruitful in some cities. The influence of sites brightly lighted at night on peregrine nesting success is not known, although some successful eyries such as the one in Baltimore receive illumination every night.

Access to buildings on weekends and after work hours is generally necessary for peregrine management. Often, preliminary discussions with building owners and top level staff and maintenance personnel can circumvent many problems. In Los Angeles, for example, window washers refused to clean windows above the seventeenth floor on a building from March to June when Peregrines nested there. On that same building, maintenance workers were attacked and driven from the roof (P. Young, unpublished report). In Springfield, Massachusetts, a female peregrine defending its nest struck a biologist 8 times, even succeeding in knocking off his protective headgear which was strapped on (T. French, personal communication). Two other complaints from building owners included worries about liability and feathers from prey items clogging up ventilation screens.

Not all urban-dwelling citizens want peregrines in the city either, especially pigeon fanciers. There are two sorts of pigeon fanciers who complain: those who like to feed feral pigeons in city parks, and the breeders of homing pigeons or other special varieties, such as tumblers and rollers which are especially vulnerable to hunting peregrines. The number of pigeon lofts in dense metropolitan living areas is sometimes unbelievable, for example in the boroughs of New York City and in Los Angeles. Several reintroduced peregrines and their progeny have been shot in the Watts district of Los Angeles, where many inner city folk keep lofts contrary to city ordinance. No one has ever been arrested. For this reason the pair of peregrines nesting near this neighborhood is no longer allowed to fledge its young. The eggs or nestlings are removed and fostered elsewhere. In 1989 however, a pigeon-fancier was arrested and fined for shooting a released captive-bred year-old peregrine in Sebastopol, California (A. Tennant, personal communication).

Prey Taken by Urban Peregrines

Previously, only Rock Doves and European Starlings (*Sturnus vulgaris*) were mentioned as food items of city peregrines by earlier authors (Culver 1919; Groskin 1947, 1952; Herbert and Herbert 1965). More recently, Barber and Barber (1983) reported the prey items taken over 3 years by Scarlett, the single female that inhabited downtown Baltimore from 1977 to 1983. Of 304 prey items found by Barber and Barber, 277 (91 percent) were Rock Doves. Certainly, pigeons do appear in the diet of peregrines in all of the 16 cities surveyed. In only one locale, Saskatoon, were pigeons considered unusual prey items for peregrines inhabiting that city (L. Oliphant, personal communication). However, pigeons were not necessarily the number one prey item in the other cities. For example, P. Redig (personal communication) noted that peregrines nesting in St. Paul and Rochester, Minnesota took many more pigeons than the pair in Minneapolis.

Roller pigeons were particularly prevalent in the diet of Los Angeles peregrines (P. Young, unpublished report) because they are more noticeable in their peculiar flight pattern, fly at higher altitudes than feral types, and being smaller, can be more easily carried from a distance. Young also noted that most often pigeons taken were all or partially white, i.e. brown and white, black and white.

Eleven bird species caught during peak migration times and one mammal, i.e. Big Brown Bat (*Eptesicus fuscus*) comprised the remainder of prey items recorded by Barber and Barber (1983). While mammals are somewhat unusual prey items for peregrines, bats are an exception (Cade 1982). The only other reports of mammals being taken were those of Norway Rats (*Rattus norvegicus*) eaten by peregrines nesting in a Montreal quarry in 1983 (D. Bird, unpublished data) and ground squirrels (*Spermophilus* spp.) in Calgary (T. Nette, personal communication). Other noteworthy observations by the Barbers were the consumption of window-killed birds and extensive caching of food items.

After Scarlett's death, the Barbers continued their study of the new pair of peregrines from 1984 to 1987 (Barber and Barber 1988). Their sample of 472 items included 26 avian species, indicating a broad diversity for the Baltimore peregrines at least. This time, Rock Doves made up only 46% of all prey taken, whereas waterfowl and shorebirds comprised 22% of their prey. They suggested that the difference may be attributed to a different food preference of the new female, i.e. she spent her first 15 months in the marshes of New Jersey prior to nesting in Baltimore. Having the smaller male present may also influence the diet of urban falcons.

A seasonal trend was noted in the taking of pigeons. The Baltimore peregrines were less interested in catching pigeons during periods of high availability of either migrants or juvenile birds. In Boston, peregrines preyed heavily upon Starlings because of a major roost nearby (T. French, personal communication).

Smaller raptors, i.e. American Kestrels (*F. sparverius*), Saw-whet Owls (*Aegolius acadicus*), have appeared in the diet of urban-dwelling peregrines. Two species noted by Barber and Barber (1983) for Baltimore were the Sora Rail (*Porzana carolina*) and Yellow-billed Cuckoo (*Coccyzus americanus*). The Sora Rail, apparently easy to catch, has shown up with unexpectedly high frequency in Saskatoon (L. Oliphant, personal communication), Winnipeg (R. Nero, personal communication), Minneapolis (P. Redig, personal communication), and Edmonton (J. Folinsbee, personal communication). Yellow-billed Cuckoos were also taken in Saskatoon (L. Oliphant, personal communication) and Boston (T. French, personal communication), while Black-billed Cuckoos (*C. erythropthalmus*) were killed by pairs in Boston, as well as in Minneapolis and Milwaukee (P. Redig, personal communication). In Milwaukee, fledgling peregrines were hunting cuckoos after dusk and caching them. In other cities, the falcons have been seen flying during the night capturing migrants blinded by bright city lights (R. Thorsell, personal communication). Perhaps not so surprising is the frequent appearance of domestic pet birds, i.e. various species of budgerigars (*Melopsittacus*), parakeets,

cockatiels and finches, either escaped or intentionally released.

Paul Young (unpublished report) documented some of the hunting behaviour of Los Angeles peregrines. "Almost accipitrine in nature" using the element of surprise, most attacks were launched from a perch on a building with very little "waiting on", as peregrines typically do. The majority of hunting was done in the vicinity of the nest site.

Attitudes Toward Urban Peregrines

Like the pigeon fanciers mentioned earlier, there exist outspoken conservationists who decry the promotion of urban-nesting peregrines, some speaking from deep conviction and others from ignorance. Some naturalists feel that peregrines belong only on cliffs in wild and rugged country, and they object on esthetic and moral or religious grounds to deliberate attempts to establish falcons in man-created environments or to put them in places where they never occurred naturally. Some worry that having peregrines in cities might downplay the need to save habitat in the wild.

Other critics have complained bitterly, sometimes viciously, that urban releases are just elaborate publicity stunts by elitists or egomaniacs who want to attract attention to themselves or who want to raise money to support their enterprises. There is no question that great publicity attends the release of falcons in cities and, especially, the establishment of a successful breeding pair. Moreover, media people have at times been carried away in an excess of zeal to report on such events. Finally, it is understandable that the sponsors of city releases want to use the opportunity to advertise their business, as well as to raise funds "for conservation", not always for the support of further work on peregrines either.

It is also undeniably true that city-dwelling peregrines provide unparallelled opportunities for public education and awareness about falcons and the problems of endangered wildlife. Urban peregrines have become the objects of much civic pride and enjoyment by millions of folk whose only other appreciation of wildlife comes from the occasional nature film on television. When "Scarlett" came to Baltimore and established herself on the 33rd floor of the United States Fidelity and Guaranty Building in 1977, she enlivened the whole city; and the history of her amours with "Rhet" and a series of mates over the next seven years captivated a following of many thousands of people across the nation. She died in 1984 shortly after having raised a brood of her own young for the first time, but the USF&G eyrie remains occupied by a pair of falcons to this day; and there are few persons in the Baltimore area who could not give a fair account of peregrine biology and conservation. Much the same is true in other cities where peregrines are now nesting.

Predictably, many local groups and state agencies have been overcome with "falcon fever" and now want to conduct their own city releases because of the favorable public relations and fund-raising opportunities associated with such activities. This enthusiasm is fine so long as the welfare of the peregrines and the priorities of the regional recovery plans are kept foremost. As long as the best interests and safety of the falcons remain the first concern, the secondary benefits of publicity, fund raising, and public education are added incentives, which no one should have to decry. Only when local groups or agencies begin to think first about publicity and money are things likely to go awry through a poor choice of location or birds for release. Those in charge of local projects must learn how to resist sponsors who have money but whose building is unsuitable. They should become wary of buying from commercial breeders, or entrepreneurial middlemen, falcons whose manner or rearing and whose geographic origins or genetic backgrounds are unknown or suspect, especially in Canada and the western states where it has always been official policy to release only birds of indigenous *anatum* stock.

Based on the phenomenal increase in the population of urban-nesting peregrines and a reproductive success parallelling that of rural-nesting birds, it is safe to say that urban peregrines are here to stay and to multiply! There is obviously much interchange between urban and rural sites and hence, the pairs occupying urban sites should be viewed as integral parts of the overall population and not as oddities.

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Impact of Forced Renesting on Reproductive Success in Ungava Bay Peregrine Falcons, *Falco peregrinus*

David M. Bird[1], Ian Ritchie[1], James D. Weaver[2], and Reed Bowman[3]

[1]Macdonald Raptor Research Centre of McGill University, 21,111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0
[2]The Peregrine Fund, Inc., 5666 West Flying Hawk Lane, Boise, Idaho 83709
[3]National Audubon Society, Research Department, 115 Indian Mound Trail, Tavernier, Florida 33070

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The first clutches were removed from eight pairs of the Peregrine Falcon nesting in Ungava Bay in 1984 and 1986 to induce the laying of a replacement clutch, but only one pair renested to produce two young.

En 1984 puis en 1986, la première couvée de huit couples de Faucons pèlerins qui nidifiaient dans la Baie d'Ungave a été enlevée dans le but d'inciter la ponte d'une couvée de remplacement. Un couple seulement a renidifié et a produit deux jeunes.

Key Words: Peregrine Falcon, *Falco peregrinus*, forced renesting, replacement clutch, Ungava Bay.

Many raptors can produce a second or replacement clutch upon loss of their first (Olendorff 1971; Morrison and Walton 1980). The technique of removing the first clutch to induce the laying of a second or even a third clutch was discovered by egg-collectors many years ago (Bent 1938).

Forced renesting, the technique of removing the first clutch to induce the laying of a second or even a third clutch, has been shown to have little impact on egg dimensions, fertility or hatchability in wild American Kestrels (*Falco sparverius*) (Bowman and Bird 1985). However, in captive kestrels seasonal declines were noted for fertility, hatchability, clutch size, egg length, eggshell thickness, and fresh egg weight (Bird and Laguë 1982).

Forced renesting is commonly used to enhance reproductive output in captive breeding programs for many species of birds of prey, most notably the endangered Peregrine Falcon (*F. peregrinus*) (Weaver and Cade 1983). Moreover, it has occasionally been used successfully as a management tool for wild peregrine nesting at southerly latitudes (Barclay 1988). While Peregrine Falcons are making a strong comeback in the eastern United States due mainly to an intensive captive breeding and release program (Barclay 1988), the number of successfully breeding pairs continues to remain low in eastern Canada despite similar programs (Holroyd and Banasch, this issue).

Ungava Bay in northern Quebec has supported a stable population of Peregrine Falcons from 1980 to 1983 (Bird and Weaver 1988). Forcing Ungava peregrines to lay replacement clutches, while artificially raising the progeny from first clutches, would provide an inexpensive source of falcon stock for release programs in southern Quebec, given that replacement clutches are as successful as first clutches.

With this in mind, we collected first clutches from three pairs of peregrines in 1984 and five pairs in 1986 from the Koksoak River north of Kuujjuaq, Quebec (latitude 58°15′) and Leaf Bay (latitude 58°45′). Nests were visited by helicopter on 9 June 1984 and 15 June 1986, respectively, and the eggs kept warm in a vinyl suitcase lined with soft foam and a hot water bottle. The eggs were subsequently transferred to a Marsh Farms Roll-X incubator (College Pets and Poultry Supplies, Toronto) and kept at a standard temperature and humidity regime for peregrine eggs (Weaver and Cade 1983). After a day or two, the eggs were again placed in the vinyl case with hot water bottle and flown by commercial airline south to the Macdonald Raptor Research Centre where they were transferred to Marsh Farms Roll-X incubators until hatching. All young in both years were fed four times daily on frozen-thawed, day-old cockerels and later released at sites in southern Quebec.

On 20 July 1984 and on 23 August 1986, respectively, we returned to the sites where clutches were removed to determine whether renesting occurred. We also examined possible alternate sites in the surrounding area. With one exception, the falcons were either absent from the area or they exhibited little no defensive behaviour, indicating a failure to renest (Table 1). The pair that did renest strongly defended two healthy young. Assuming an incubation period of 32 days and a laying interval of 2 days between eggs, the nestlings' age of

TABLE 1. Impact of removal of first clutches on subsequent reproductive success of Peregrine Falcons nesting in Ungava Bay in 1984 and 1986.

Year	Site	Initiation of clutch*	Date of removal	No. days natural incubation*	No. eggs	No. eggs fertile	No. eggs hatched	No. young fledged	No. of young in 2nd clutch
1984	A	30 May	6 June	6	3	3	1	1	—
1984	B	28 May	11 June	10	3	3	2	2	—
1984	C	2 June	11 June	3	4	1	0	0	—
1986	D	24 May	17 June	18	4	4	4	4	—
1986	E	28 May	17 June	14	4	4	4	4	—
1986	F	2 June	17 June	11	3	1**	1	0	—
1986	G	5 June	15 June	5	4	4	3	3	2
1986	H	7 June	17 June	6	3	3	3	3	—
				Totals	28	23	18	17	2

*All but C are approximations based on the known hatching date and assuming an incubation period of 32 days. The data for C were calculated on measured egg weight loss based on Burnham (1983).
**The other two eggs were addled and fertility could not be determined.

approximately 3 weeks indicates a renesting interval of roughly 2½ to 3 weeks. This concurs with the findings of Ratcliffe (1980) who calculated a mean renesting interval of 19 to 20 days for 43 renesting pairs of Peregrine Falcons in Great Britain.

Ungava peregrines were consistent in their timing for initiating laying between the two years (Table 1). Not consistent however, was the number of days from the date of the last egg laid to the removal of the clutch. Peregrines are most likely to renest if the first clutch is lost before 7 to 10 days of incubation (Ratcliffe 1980). After 10 days, the external stimuli, e.g. presence of a mate, suitable nesting site, food, etc. apparently are not strong enough to create the physiological conditions necessary for egg production and laying. Although some pairs on rare occasions have laid second clutches after incubating the first one full-term (Ratcliffe 1980), this would appear to be highly unlikely for northern-nesting falcons.

Successful laying of replacement clutches that fledged young has been documented for Gyrfalcons (*F. rusticolus*) at latitudes between 60 and 69 degrees (Platt 1976; Poole 1988). However, based on anecdotal observations by Hickey (1942) and Cade (1960), renesting attempts by peregrines at high latitudes have generally not been successful. The less migratory Gyrfalcons are often 2 to 3 weeks ahead of peregrines in their breeding chronology in Ungava Bay (D. Bird, unpublished data). The highly migratory northern peregrine populations have a much shorter breeding period in which to achieve pair-integration prior to breeding compared to sedentary populations (Fischer 1967). Also, whether the nestling period for second clutches exceeds that of first clutches in peregrines is not known. Bowman and Bird (1985) noted that second clutch young of wild kestrels took longer to fledge than first clutch ones.

Certainly young peregrines fledging from northern nests would require enough time to hone flight and hunting skills before migrating to parts as far south as Argentina. It is questionable whether the two young produced by the renesting falcons could achieve that. Being three weeks of age on 24 August, they would still be practising foraging skills in Ungava Bay well into late September.

Egg hatchability was 78 percent (18/23), indicating little, if any, effect of handling them throughout the study on incubation success. Considering only those eggs receiving anywhere from 6 to 18 days of natural incubation, the hatchability rose to 100 percent. Lowered hatchability in artificially-incubated eggs of captive peregrines without any prior natural incubation has been well-documented (Burnham 1983). The only way to assure a period of 7 to 10 days natural incubation in northern peregrines would be to actually observe the nesting pair to determine egg-laying dates beforehand. This is somewhat impractical for most nest sites in Ungava Bay due to hazardous, unpredictable weather conditions, not to mention the cost factor.

Our findings concur with earlier observations by Hickey (1942) and Cade (1960). We conclude then that removal of first clutches to induce the laying of a second one is not a practical method of augmenting the numbers of Peregrine Falcons to be released in southern Canada.

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Levels of Contaminants in Canadian Raptors, 1966 to 1988; Effects and Temporal Trends

DAVID G. NOBLE and JOHN E. ELLIOTT

Canadian Wildlife Service, Ottawa, Ontario K1A 0H3

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Organochlorine and mercury residue concentrations in eggs and body tissues of twenty-seven species of raptors collected in Canada between 1966 and 1988 are summarized. A few individuals had liver mercury or DDE concentrations at levels associated with poisoning. During the late 1960s and early 1970s, levels of DDE in some eggs of Bald Eagles, Osprey, Red-tailed Hawks, Northern Harriers, Merlins, Prairie Falcons, and Great Horned Owls were high enough to cause eggshell thinning. In the 1980s, elevated DDE levels were found in some eggs of Sharp-shinned Hawks, Cooper's Hawks and Merlins. Dieldrin and heptachlor epoxide levels in eggs also exceeded minimum critical levels in a few individuals of a number of species. The significance of the detected concentrations are discussed in relation to the status of those populations. DDE, dieldrin and heptachlor epoxide concentrations in eggs generally declined over the period of sampling. Although some bird-eating raptors are still highly contaminated, population declines in many species can be attributed to a number of factors, including loss of suitable habitat.

Les concentrations de résidus de mercure et d'organochlorés dans les oeufs et les tissus corporels de vingt sept espèces de rapaces ramassées au Canada entre 1966 et 1988 sont compilés. Quelques individus avaient des concentrations de mercure ou de DDE dans le foie à des niveaux associés aux empoisonnements. Vers la fin des années 60 et au début des années 70, les niveaux de DDE dans certains oeufs de Pygargue à tête blanche, de Balbuzard, de Buse à queue rousse, de Busard Saint-Martin, de Faucon émerillons, de Faucon des Prairies et de Grand-duc d'Amérique étaient assez élevés pour causer un amincissement de la coquille. Pendant les années 80, des taux de DDE élevés ont été trouvés dans certains oeufs d'Epervier brun, d'Epervier de Cooper et de Faucon émerillon. Les niveaux de dieldrine et d'époxyde d'heptachlore dans les oeufs dépassaient aussi les taux critiques minimums dans quelques spécimens d'un certain nombre d'espèces. L'importance des concentrations relevées est discutée en fonction du statut des populations en question. Les concentrations de DDE, de dieldrine et d'époxyude d'heptachlore dans les oeufs diminuaient, en général, pendant la période d'échantillonage. Même si les rapaces mangeurs d'oiseaux sont encore considérablement contaminés, le déclin des populations de beaucoup d'espèces peut être attribué à un certain nombre de facteurs dont la perte d'un habitat adéquat.

Key Words: Raptors, Canada, organoclorines, mercury, DDE concentrations, diedrin, heptachlor epoxide, population declines.

Since the discovery of synthetic pesticides such as DDT and dieldrin in wildlife, birds of prey have been identified as being particularly vulnerable (Newton 1979). Because of their position at the top of terrestrial or aquatic food chains, and their relatively inefficient elimination of lipophilic contaminants (Walker and Stanley 1986), raptors tend to accumulate high levels of those substances. Moreover, many species appear to be relatively sensitive to the eggshell-thinning effects of DDE (Cooke, 1973; Fyfe et al. 1988) and to the direct toxic effects of other organochlorines such as dieldrin (Lockie et al. 1969).

Early indications of the dangers posed by DDT and other organochlorines to North American raptors included the rapid declines in numbers of Osprey *Pandion haliaetus* in the eastern United States (Ames 1966) and Bald Eagles, *Haliaeetus leucocephalus* in Ontario (Postupalsky 1971), in conjunction with reports of thin-shelled eggs that either disappeared or failed to hatch. In 1965, attention focussed on the plight of the Peregrine Falcon, *Falco peregrinus*, particularly the *anatum* race, which had been extirpated from nearly all of its former breeding range in eastern North America (Hickey 1969).

Use of the high-molecular-weight organochlorine pesticides (such as DDT, dieldrin, heptachlor, chlordane, BHC and mirex) and many applications of mercury have been restricted in Canada and the United States since the early 1970s. However, there continue to be reports of high levels in wildlife (e.g., Clark and Krynitsky 1983; Blus et al. 1987). This paper summarizes data on environmental contaminants in raptors collected by the Canadian Wildlife Service (CWS) since 1966. A more detailed breakdown of the data is available in a CWS Technical Report (Noble and Elliott *in press*).

Methods

The data were retrieved from the CWS National Registry of Toxic Chemical Residues (Elliott et al. 1987), a computerized repository of data on

TABLE 1. Summary of minimum critical levels (in mg/kg, wet weight) of major environmental contaminants in eggs, brains and livers of raptors.

Conntaminant Level (mg/kg) diagnostic of:	(1) acute toxicity		(2) reproductive effects
	Brain	Liver	Eggs
Dieldrin	> 5.0[a]	3-10[b]	> 1.0[c]
Oxychlordane	1.1-5.0[d]	3-10[b]	
Heptachlor epoxide	3.4-8.3[d]	3-10[b]	> 1.5[c]
DDE	250[f]	100[b]	1.2-30[g]
PCBs	500-3000[h]		> 50[i]
HCB			> 5.0[j]
Mercury	> 50[k]	20-45[k]	>0.5[l]

[a]Stickel et al. 1969; [b]Cooke et al. 1982; [c]Lockie et al. 1969; Wiemeyer et al. 1975; [d]Stickel et al. 1979; [e]Henny et al. 1983; [f]Stickel et al. 1984; [g]Fyfe et al. 1988, Lincer 1975; [h]Heath et al. 1972; [i]Hoffman et al. 1987; [j]Boersma et al. 1986; [k]Scheuhammer 1987; [l]Fimreite 1971; Heinz 1979.

environmental contaminants in Canadian wildlife. We obtained data on nineteen species of hawks, eagles and vultures and eight species of owls. The contaminants selected include DDE (the main metabolite of DDT), dieldrin, heptachlor epoxide (the major metabolite of heptachlor), oxychlordane (a metabolite of cis and trans chlordane), hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs) and mercury.

Data are presented on the basis of wet weight. This minimizes variation due to changes in lipid content during development of eggs (Peakall and Gilman 1979) or due to physiological factors affecting levels in tissues. Concentrations in dehydrated eggs were adjusted for estimated water loss. Results which were below the detection limit were assigned a value of one half the detection limit, normally 0.005 mg/kg (O.E.C.D. 1981). Geometric means were determined for samples grouped by time period of collection and geographic region. The three time periods represent, respectively, the era of extensive organochlorine use (1965-1972), immediately post-ban (1973-1979) and the recent situation (1980-1988).

For species for which sufficient data were available, we investigated changes in contaminant levels over time by conducting pair-wise t-tests of samples grouped by region. In addition, we used the general linear model (GLM) procedure of SAS to test for a significant directional trend.

Methods of collection of the specimens varied over the twenty-three year period. Many eggs were collected opportunistically at the end of the breeding season, and therefore represent mainly nonviable eggs. However, many fresh eggs, particularly those of Merlins, *Falco columbarius* and Prairie Falcons, *Falco mexicanus,* were also collected. Unless stated otherwise, eggs analyzed were from separate nests.

Tissues were usually obtained from birds found dead. Although breast muscle, fat, gonads and whole bodies were also analyzed, only liver and brain residues are reported here. Further details of the sample collection, preparation and storage are described in Noble and Elliott (*in press*).

The earliest data included are from 1966. Prior to 1969, only DDE and dieldrin concentrations are presented, due to the confounding influence of PCBs at that time. A method of separating peaks of PCBs from those of other organochlorines was developed on behalf of CWS in 1969 (Reynolds 1969). We have presented the PCB data on the basis of a 1:1 ratio of Aroclors 1254 and 1260. Total mercury was determined by wet digestion followed by flameless atomic absorption spectrophotometry (AAS), as described by Hatch and Ott (1968).

Until 1984, all analyses were carried out at the Ontario Research Foundation, following procedures described by Reynolds and Cooper (1975). Since 1984, samples have been analyzed at the National Wildlife Research Centre in Hull, using methods described in Peakall et al. (1986).

Results and Discussion

Evaluation of the effects of detected contaminants

The objective of this section is to compare the detected concentrations with critical values derived from the literature. Minimum critical levels and their sources are summarized in Table 1, and discussed in more detail in Peakall et al. (*this issue*).

The acute lethal toxicities of organochlorines and mercury have been experimentally determined in few raptor species: Goshawks, *Accipiter gentilis* (Borg et al. 1970), Red-tailed Hawks, *Buteo jamaicensis* (Fimreite and Karstad 1971) and American Kestrels, *Falco sparverius* (Porter and Wiemeyer 1972). Hence, we supplemented the findings of those studies with experimental work on other birds (Stickel et al. 1969; Heath et al. 1972; Stickel et al. 1979; Cooke et al. 1982; Stickel et al. 1984), to derive the critical brain and liver values in Table 1.

Laboratory studies on the effects of organochlorines on reproduction in raptors have been limited to work on Screech Owls, *Otus asio* (McLane and Hughes 1980), Barn Owls, *Tyto alba* (Mendenhall et al. 1983) and American Kestrels (e.g., Wiemeyer et al. 1986). Minimum critical values were determined from the results of those and other studies on the relationship between contaminant levels in eggs and reproductive parameters (e.g., Lockie et al. 1969; Enderson and Berger 1970; Snyder et al. 1973; Wiemeyer et al. 1975; Henny et al. 1983; Hoffman et al. 1987; Fyfe et al. 1988). Note that because of possible covariance between contaminants or with environmental effects, a cause and effect relationship cannot be assumed in most field studies.

Incidences of raptor mortality due to contaminants

Concentrations in brains and livers are presented in Appendix 1A, 1B. A very small proportion of the raptor tissue samples analyzed were found to contain any contaminants at levels diagnostic of acute toxicity. In 1970, the liver of a Bald Eagle from northern Ontario was found to contain 42 mg/kg mercury, and the liver of one of three Turkey Vultures, *Cathartes aura*, collected in the same year contained 60 mg/kg mercury. In the early 1980s, DDE in the liver of one of seven Sharp-shinned Hawks, *Accipiter striatus,* collected in British Columbia exceeded 100 mg/kg, the critical value proposed by Cooke et al. (1982). Although not diagnostic of pesticide poisoning, the brains of two American Kestrels found dead in Ontario in 1987 contained dieldrin in excess of 2 mg/kg and heptachlor epoxide in excess of 1 mg/kg (Barker, personal communication).

As there has traditionally been no formal system in place to retrieve and analyze raptors found dead, we cannot accurately assess the incidence of raptor mortality due to contaminants. Although the infrastructure for testing dead wildlife for toxic substances has improved, most poisoned birds are seldom recovered. Hence, actual mortality rates are undoubtedly higher than those observed.

Poisoned raptors have been reported more frequently in the United States than in Canada. Dieldin was implicated in the deaths of Bald Eagles (Kaiser et al. 1980), Peregrine Falcons (Reichel et al. 1974) and Red-shouldered Hawks, *Buteo lineatus* (Sundlof et al. 1986). Oxychlordane was considered to be the cause of the deaths of two Red-shouldered Hawks and a Great Horned Owl, *Bubo virginianus* (Blus et al. 1983) and heptachlor epoxide was implicated in the deaths of three Golden Eagles, *Aquila chrysaetos*, an American Kestrel, and a Rough-legged Hawk, *Buteo lagopus* (Henny et al. 1984). In 1980, a Cooper's Hawk, *Accipiter cooperi,* was found dead in Maryland with lethal concentrations of DDT in its brain (Prouty et al. 1982). In New York, two of twenty Great Horned Owls examined were considered to have been poisoned by either DDE, dieldrin or PCBs (Stone and Okoniewski 1983), and an American Kestrel was found to contain toxic concentrations of both DDT and dieldrin in its brain (Stone 1981). Many of these deaths may involve Canadian birds. A Merlin found dead in New Mexico with more than 9 mg/kg heptachlor epoxide in its brain was found to be banded in Alberta (Henny et al. 1976).

Although not documented in North America, poisoning by mercury has been reported in European raptors (Borg et al. 1969; Delbeke et al. 1984).

Levels and reproductive effects

During the late 1960s and early 1970s, a number of Canadian raptor populations were found to have elevated levels of organochlorines in their eggs. By the 1980s, significant contamination was reported only in eggs of Sharp-shinned Hawks, Cooper's Hawks, Merlins and Peregrine Falcons.

The pattern of contamination by species (*see* Figure 1 for recent data) confirms the maxim that species which feed primarily on migratory birds are most contaminated, whereas species feeding mainly on mammals are least contaminated. Local pesticide use, food from aquatic sources and wintering range may also be important factors (Noble and Elliott *in press*).

Accipiters were relatively contaminated. Between 1980 and 1988, three of thirteen Cooper's Hawk eggs and five of nine Sharp-shinned Hawk eggs collected in southern Ontario contained DDE in excess of 10 mg/kg (Table 2). DDE egg residues of this magnitude have been associated with significant eggshell thinning in North American accipiters (Snyder et al. 1973) and Eurasian Sparrowhawks *Accipiter nisus* (Newton et al. 1986). During the same time period, dieldrin was detected at a level greater than 1 mg/kg in one Sharp-shinned Hawk egg. Throughout this paper, we have used 1 mg/kg dieldrin as the minimum critical level in the eggs of raptors, based on the studies of Lockie et al. (1969) and Wiemeyer et al. (1975). However, there may be considerable interspecific differences in susceptibility, as 3 mg/kg dieldrin was found to have no effect on reproduction in Screech Owls (Mendenhall et al. 1983).

Snyder et al. (1973) demonstrated a significant correlation between the percentage of birds in the diet of individual Cooper's Hawks and the DDE content of their eggs. Of the accipiters, Sharp-shinned Hawks depend most on migratory insectivorous birds, whereas Northern Goshawks feed mainly on resident birds and mammals

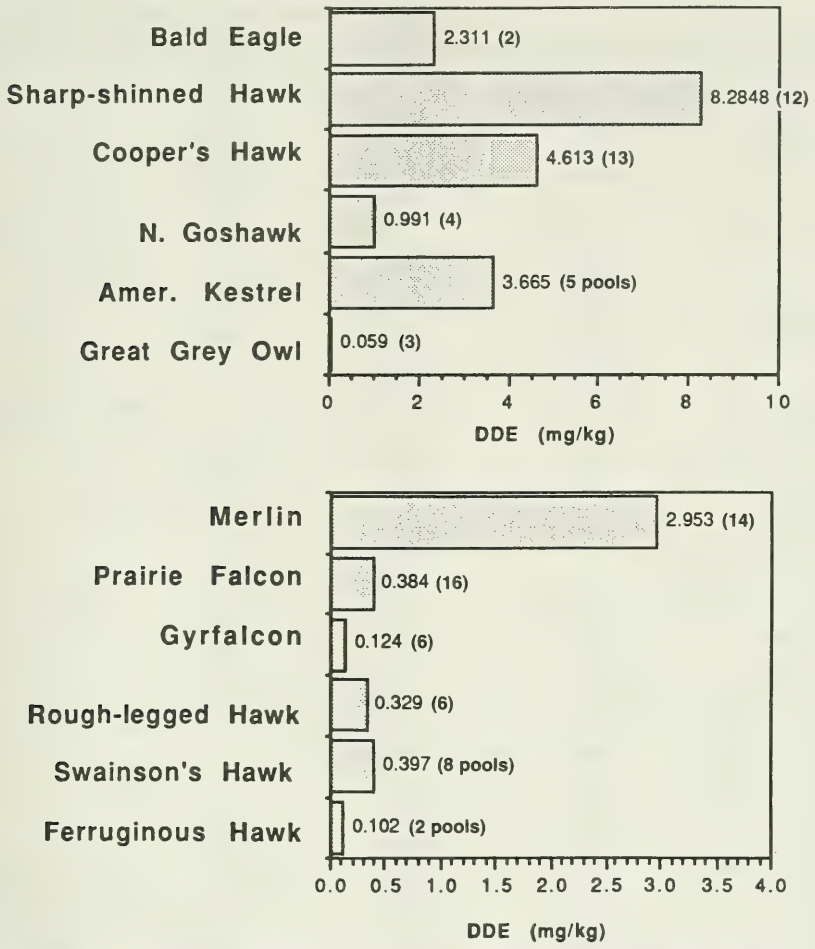

FIGURE 1. Comparison of DDE residue levels in eggs of raptors during the 1980s; A: from Ontario and east during the 1960s; B: from western Canada. Values are geometric means and sample sizes, the latter in parenthesis).

(Sherrod 1978). Comparison of the organochlorine content of eggs of all three accipiters (see Appendix 2A) is consistent with that hypothesis.

Overall, buteos were considerably less contaminated than accipiters (Appendix 2B). Four Red-tailed Hawk eggs collected in 1968 were the only eggs to contain DDE residues in excess of 15 mg/kg (Table 2), a level associated with minor eggshell thinning in this species (Seidensticker and Reynolds 1971). Dieldrin concentrations exceeded 1 mg/kg in five Red-tailed Hawk eggs, two Swainson's Hawk, *Buteo swainsoni*, eggs and two Ferruginous Hawk, *Buteo regalis,* eggs, all collected in the late 1960s (Table 2). Heptachlor epoxide levels exceeded the minimum critical value of 1.5 mg/kg (Henny et al. 1983) in one Red-tailed Hawk egg, one Swainson's Hawk egg, one Ferruginous Hawk egg and one Rough-legged Hawk egg (Table 2). However, there is some evidence that Swainson's Hawks, at least, can tolerate concentrations in excess of 2.5 mg/kg (Henny et al. 1984). One Red-tailed Hawk egg also contained 1.6 mg/kg mercury, slightly more than the level associated with detrimental reproductive effects in other birds (Fimreite, 1971; Heinz 1979).

Low levels of DDE in eggs of Ferruginous and Swainson's hawks in the Dakotas, during the 1970s, were attributed to a diet of small mammals (Stendell et al. 1988). Small mammmals dominate the diet of most buteos (Lincer et al. 1971; Schmutz and Schmutz, 1980; Risley 1983). As in Stendell et al.'s (1988) and Bechard's (1981) study, contaminant residues in Swainson's Hawks were similar to those in coexisting Ferruginous Hawks, despite the fact that the former species is highly migratory, wintering south to Argentina (Palmer 1988).

TABLE 2. Proportion of eggs with threshold critical levels of DDE, dieldrin, heptachlor expoxide or mercury, likely to affect productivity. The critical values are 10 mg/kg DDE (except where indicated), 1 mg/kg dieldrin, 1.5 mg/kg heptachlor expoxide and 0.5 mg/kg total mercury. No pooled samples are included.

Region	Years	DDE	Dieldrin	HE	Mercury
Northern Goshawk					
Atlantic	1965-72	0/1	0/1	0/1	–
Ontario	1980-88	0/4	0/4	0/4	–
Cooper's Hawk					
Ontario	1980-88	3/13	0/13	0/13	–
Prairies	1965-72	1/17	1/17	0/17	0/7
	1973-79	0/3	1/3	0/3	0/1
Sharp-shinned Hawk					
Atlantic	1980-88	0/3	0/3	0/3	–
Ontario	1980-88	5/9	1/9	0/9	–
Prairies	1965-72	0/1	0/1	0/1	0/1
Red-tailed Hawk					
Ontario	1965-72	0/1	0/1	0/2	0/2
Prairies	1965-72	4/46	5/46	1/42	1/14
British Columbia	1965-72	0/1	0/1	0/1	–
Red-shouldered Hawk					
Ontario	1973-79	0/3	0/3	0/3	–
Swainson's Hawk					
Prairies	1965-72	0/18	2/17	1/17	–
	1973-79	0/1	0/1	0/1	0/1
Ferruginous Hawk					
Prairies	1965-72	1/50	2/49	1/50	–
Rough-legged Hawk					
North	1965-72	0/13	0/13	0/3	0/3
	1973-79	0/1	0/1	0/1	–
	1980-88	0/6	0/6	1/6	0/2
Bald Eagle[1]					
Atlantic	1965-72	1/1	0/1	–	0/1
	1980-88	0/2	–	–	–
Ontario	1965-72	16/16	10/16	0/14	5/15
	1973-79	2/2	1/2	0/2	0/2
Prairies	1965-72	4/13	2/13	0/5	1/10
Golden Eagle					
Prairies	1965-72	0/9	0/9	0/9	0/6
	1973-79	0/12	1/12	0/12	0/12
North	1973-79	0/1	0/1*	–	–
Osprey[2]					
Atlantic	1965-72	3/3	0/1	–	0/3
Ontario	1965-72	4/8	0/8	0/1	0/8
Prairies	1973-79	1/2	0/2	0/2	0/2
British Columbia	1965-72	1/2	0/2	0/2	–
North	1973-79	2/2	0/2	0/2	0/2
Northern Harrier					
Quebec	1965-72	1/1	0/1	0/1	0/1
Prairies	1965-72	3/22	3/22	1/22	0/8
Merlin[3]					
N. Quebec	1965-72	1/1	0/1	0/1	1/1
Prairies	1965-72	88/165	32/165	13/165	8/93
	1973-79	129/159	19/159	23/159	1/141
	1980-88	5/14	0/14	3/14	-
British Columbia	1965-72	1/1	0/1	0/1	3/3
North	1973-79	4/4	2/4	0/4	0/4
Prairie Falcon[4]					
Prairies	1965-72	154/249	17/249	9/249	17/229
	1973-79	132/216	12/216	16/216	0/180
	1980-88	3/16	6/16	0/16	0/12
Peregrine Falcon (*anatum*)					
Atlantic	1965-72	1/1	0/1	0/1	0/1
Quebec	1980-88	4/7	3/7	0/7	

TABLE 2. *Concluded*

Region	Years	DDE	Dieldrin	HE	Mercury
Prairies	1965-72	5/5	3/5	0/5	1/5
	1973-79	12/20	2/20	0/20	1/5
	1980-88	8/14	3/14	3/14	3/11
North	1965-72	6/6	1/6	0/6	0/6
	1973-79	4/4	2/4	0/4	1/3
	1980-88	6/9	1/9	1/9	–
Peregrine Falcon (*tundrius*)					
Quebec	1965-72	4/10	4/10	–	–
	1973-79	3/4	3/4	0/4	1/4
	1980-88	2/10	2/10	0/10	–
North	1965-72	7/23	8/22	0/15	5/23
	1973-79	13/20	4/20	3/20	0/19
	1980-88	5/19	4/19	3/19	0/8
Peregrine Falcon (*pealei*)					
British Columbia	1965-72	7/12	0/12	0/6	7/10
	1980-88	0/4	0/4	0/4	–
Gyrfalcon					
North	1965-72	0/1	0/1	0/1	1/1
	1973-79	0/10	0/10	0/10	0/4
	1980-88	0/6	1/6	0/6	1/1
American Kestrel					
Atlantic	1965-72	0/1	0/1	–	–
Prairies	1965-72	1/8	1/8	1/8	0/3
Great Horned Owl					
Ontario	1965-72	0/1	0/1	–	–
Prairies	1965-72	6/30	0/30	2/29	0/7
North	1965-72	0/1	0/1	0/1	1/1
Snowy Owl					
North	1973-79	0/1	0/1	0/1	–
Burrowing Owl					
Prairies	1965-72	0/1	0/1	0/1	0/1
Great Grey Owl					
Minnesota	1980-88	0/3	0/3	0/3	–
Long-earned Owl					
Prairies	1965-72	0/7	0/7	0/7	0/3
Short-eared Owl					
Prairies	1965-72	0/6	0/6	0/6	–

[1]Bald Eagle: critical value of DDE = 6 mg/kg; [2]Osprey: critical value of DDE = 4 mg/kg; [3]Merlin: critical value of DDE = 5 mg/kg; [4]Prairie Falcon: critical value of DDE = 1.2 mg/kg.

Bald Eagles, which feed on a variety of fish, birds and carrion, had high concentrations of contaminants in their eggs (Appendix 2C). Twenty-three of 34 eggs contained DDE residues in excess of 6 mg/kg (Table 2), a value associated with significant eggshell thinning in this species (Wiemeyer et al. 1984). Maximum values of DDE were 100 mg/kg, in areas of northern Ontario where reproductive failures were common (Grier 1974). Six eggs contained more than 2 mg/kg dieldrin. Concentrations of heptachlor epoxide and other organochlorines were relatively low, and mercury exceeded 1 mg/kg in only two eggs (Table 2).

In eggs of Golden Eagles, which feed primarily on mammals (Sherrod 1978), only dieldrin (at 2.12 mg/kg in one egg from Alberta) was found at concentrations associated with reduced productivity in a Scottish eagle population (Lockie et al. 1969).

In contrast, eleven Osprey eggs were found to contain more than 4 mg/kg DDE (Table 2). This concentration has been associated with 15% eggshell thinning in this species, and was proposed as the maximum level of DDE sustainable by a stable population (Wiemeyer et al. 1988). Two eggs collected in the Yukon contained mercury at levels within the hazardous range.

Northern Harriers, *Circus cyaneus,* may have been affected by organochlorines prior to the 1970s. Four eggs from the Prairies contained more than 10 mg/kg DDE and one egg contained 5 mg/kg dieldrin (Table 2).

Falcons, which appear to be relatively susceptible to organochlorines (Fyfe et al. 1988)

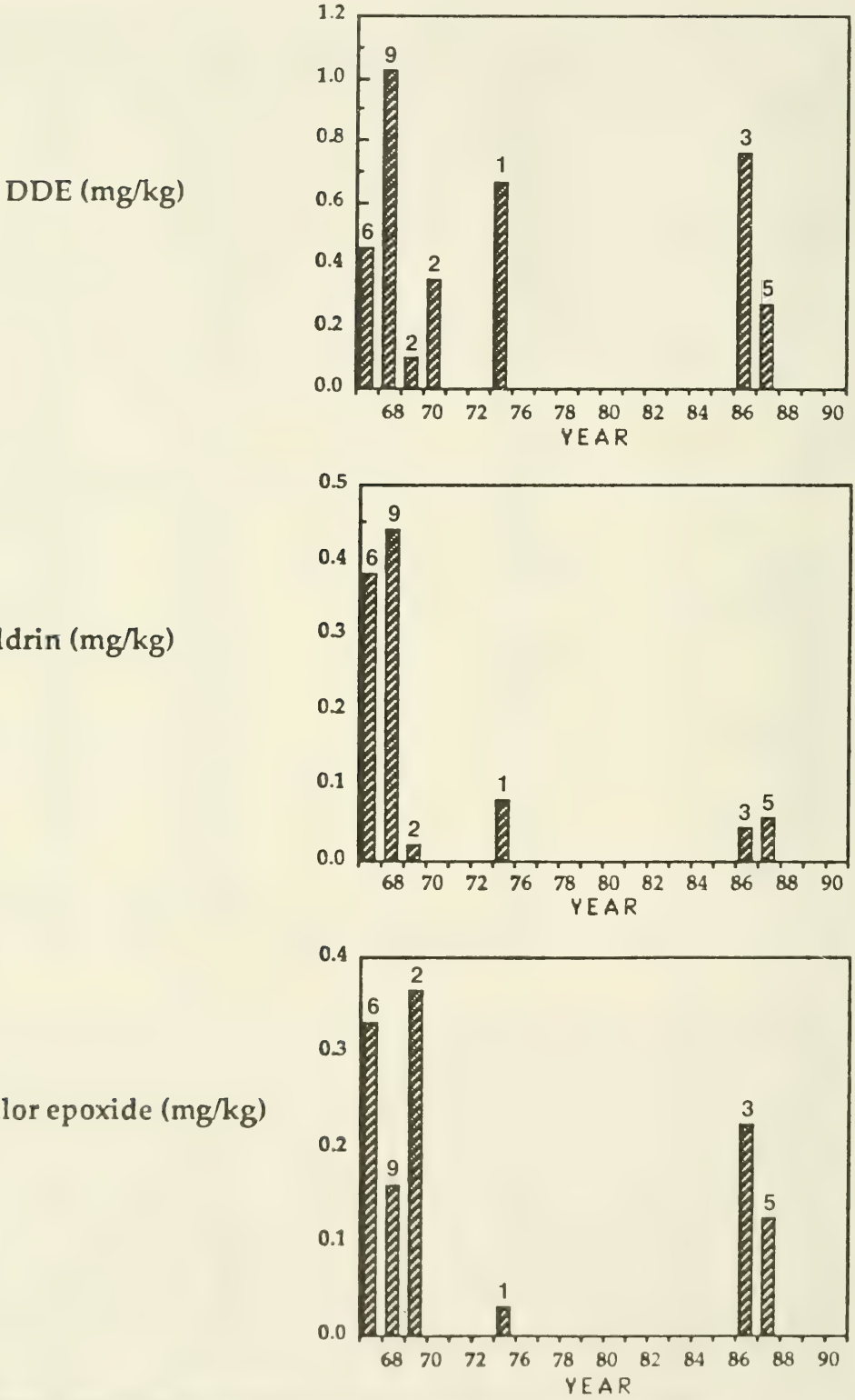

FIGURE 2. Changes in residue levels in eggs of Swainson's Hawks collected in the Prairie provinces.

were found to be highly contaminated (Appendix 2D). Many Merlin eggs collected in the Prairies prior to 1973 contained DDE, dieldrin and heptachlor epoxide in excess of critical values (Table 2). By 1988, no eggs contained elevated levels of dieldrin, but DDE and heptachlor epoxide continued to be detected at relatively high concentrations (Table 2). Dieldrin levels were as high as 5.6 mg/kg, and heptachlor epoxide levels attained 9 mg/kg. Fox and Donald (1980) reported significant behavioural effects in Merlins where DDE concentrations in eggs exceeded 8 mg/kg. Significant eggshell thinning is predicted to occur where the mean content of DDE in eggs exceeds 5 mg/kg (Fyfe et al. 1988). The Richardson's race of Merlin which inhabits the Prairies feeds mainly on small flocking birds such as larks, longspurs and sparrows (Hodson 1978) although some individuals specialize in urban birds (Palmer 1988).

Analyses of a number of Prairie Falcon eggs collected between 1966 and 1988 in the same areas as the Merlins revealed relatively high concentrations of DDE, dieldrin, heptachlor epoxide and mercury (Appendix 2D). DDE concentrations as low as 1.2 mg/kg in eggs have been predicted to cause significant eggshell thinning, and to reduce productivity in this species (Fyfe et al. 1988). Prairie Falcons in Canada are mainly resident, and feed on a variety of small bird and mammals (Palmer 1988).

DDE residues in all eggs of Gyrfalcons, *Falco rusticolus* were less than 15 mg/kg, but exceeded 8 mg/kg in one egg. This arctic species feeds mainly on resident prey (Lincer et al. 1970). All American Kestrel eggs analyzed prior to 1973 contained less than 10 mg/kg DDE, although one egg was high in dieldrin (1.25 mg/kg) and heptachlor epoxide (4.8 mg/kg) (Appendix 2D). During the late 1980s, mean DDE in five pools of Kestrel eggs from Ontario ranged from 0.44 to 10.8 mg/kg, but levels of all other contaminants were low (Table 4; Appendix 2D). Kestrels feed mainly on invertebrate prey (Sherrod 1978), but often in agricultural areas with a relatively high use of pesticides.

Many eggs of Peregrine Falcons contained DDE in excess of 15 mg/kg. The toxicological effects of DDE and other organochlorines on this species are discussed elsewhere in this issue (Peakall et al.)

Owls were relatively uncontaminated (Appendix 2E), but we lack recent data. Only eggs of the Great Horned Owl were found to contain potentially hazardous levels of organochlorines, up to 16 mg/kg in a few samples. DDE concentrations of this magnitude have been associated with eggshell thinning in Barn Owls (Klaas et al. 1978). Two Great Horned Owl eggs also contained more than 1.5 mg/kg heptachlor epoxide (Table 2).

None of the eggs of Snowy Owl, *Nyctea scandiaca*; Great Grey Owl, *Strix nebulosa*; Long-eared owl, *Asio otus*; Short-eared Owl, *Asio flammeus* or Burrowing Owl, *Speotyto cunicularia*, were found to have significant amounts of any contaminants. This is probably related to their basically mammalian diet (Godfrey 1986), a food source usually low in organochlorines (Lincer and Sherburne 1974).

Temporal Changes

Data permitting the evaluation of temporal trends in contaminant residues are limited. Only eggs, which tend to be uniform in fat and water content, provide a standardized sample with which to compare among years. As the number of eggs collected at a particular location was insufficient, in most cases, to detect statistically significant differences, we have pooled eggs from different regions. Nevertheless, the extreme variability in contaminant levels in eggs, presumably due to individual and geographic differences in exposure, meant that few trends could be discerned.

In the Prairies, contaminant residues in the eggs of four species were analyzed for temporal trends. Because earlier chemical analyses did not usually permit the identification of PCBs, chlordane metabolites, HCB or HCH, long-term trends are available only for DDE, dieldrin and heptachlor epoxide.

In eggs of Swainson's Hawk from Saskatchewan and Alberta, dieldrin levels, but not DDE or heptachlor epoxide, have declined significantly since the late 1960s (Figure 2). In eggs of Ferruginous Hawk, there were no significant declines in any of those three compounds (*see* Appendix 2B).

In eggs of Prairie Falcons from Saskatchewan and Alberta, DDE, dieldrin, heptachlor epoxide, oxychlordane and PCBs generally declined between 1968 and 1988 (*see* Appendix 2D). HCB egg concentrations, however, increased during this time period. Merlins showed overall declines in DDE, dieldrin and heptachlor epoxide (Figure 3). Pairwise comparisons of residue levels found in viable eggs, revealed that DDE and heptachlor epoxide residues increased significantly between the earliest time period and the mid-1970s. Concentrations of all three compounds declined significantly in the 1980s, although heptachlor epoxide levels did not differ significantly from those in the earliest collections.

Very little long-term data are available for eastern Canada. If the analyses reported by Grier (1982) are included, it is possible to examine changes in contaminant levels in eggs of Bald Eagles from northern Ontario (Figure 4). Grier,

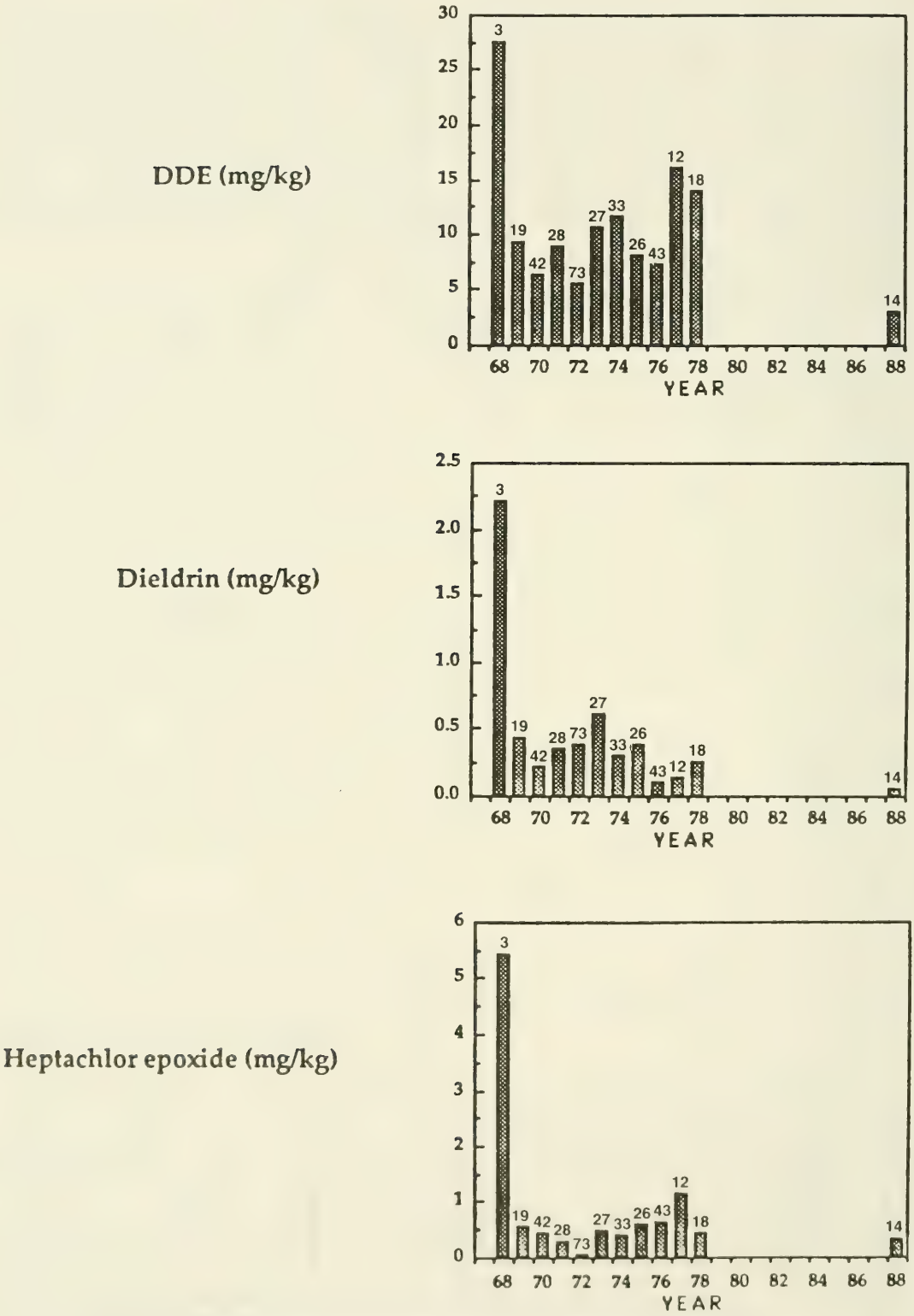

FIGURE 3. Changes in residue levels in eggs of Merlins collected in the Prairie provinces.

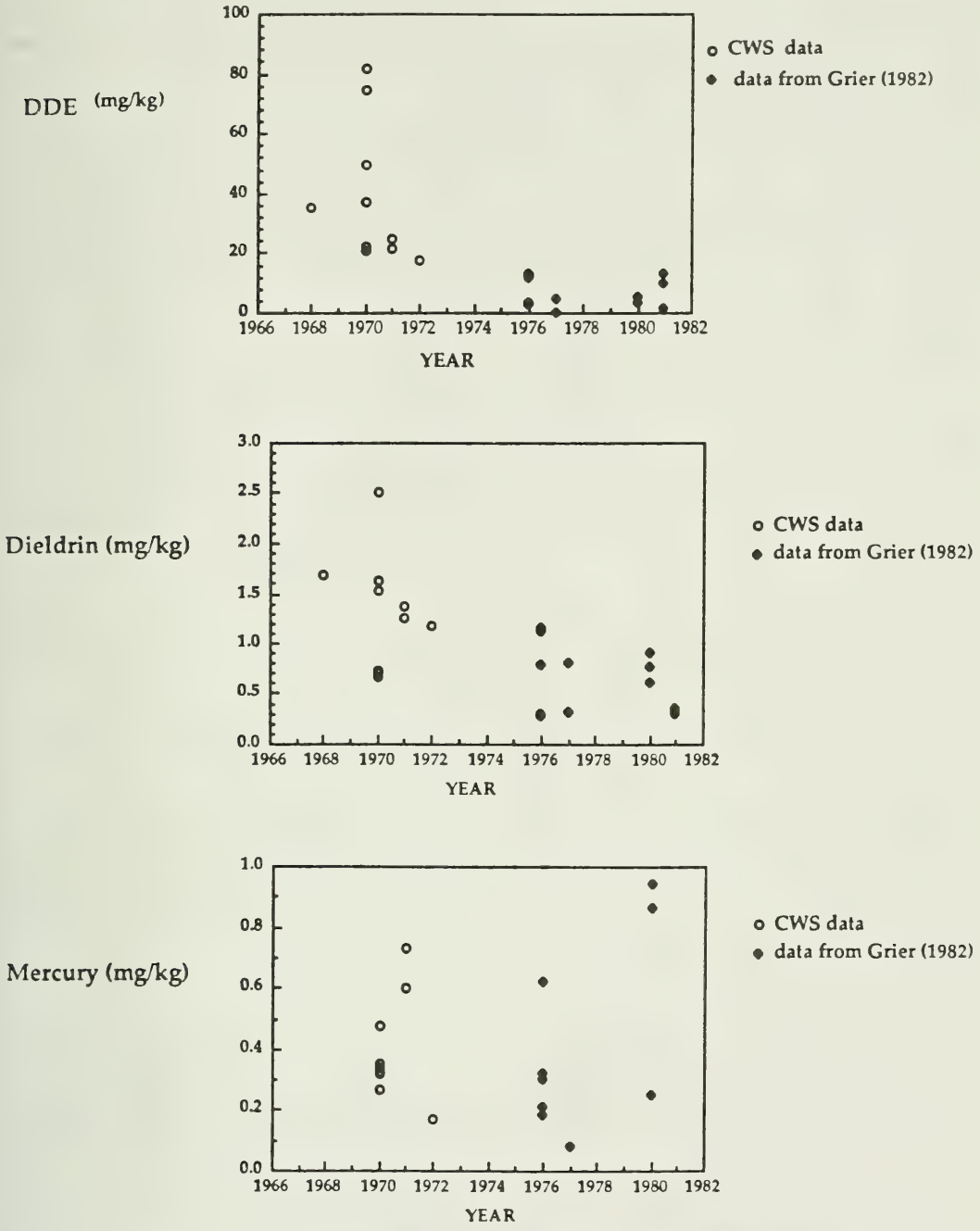

FIGURE 4. Changes in residue levels in eggs of Bald Eagles from northwestern Ontario.

using some of the data reported here, found that DDE but not PCBs, dieldrin or mercury, declined in Bald Eagle eggs between 1970 and 1982.

Two arctic species were sampled at enough locations to permit some analysis of temporal trends. In eggs of Rough-legged Hawk, comparisons between the earliest collections and those in the 1980s, revealed no significant differences in DDE, dieldrin or heptachlor epoxide. In eggs of Gyrfalcons, no significant trends in any contami-

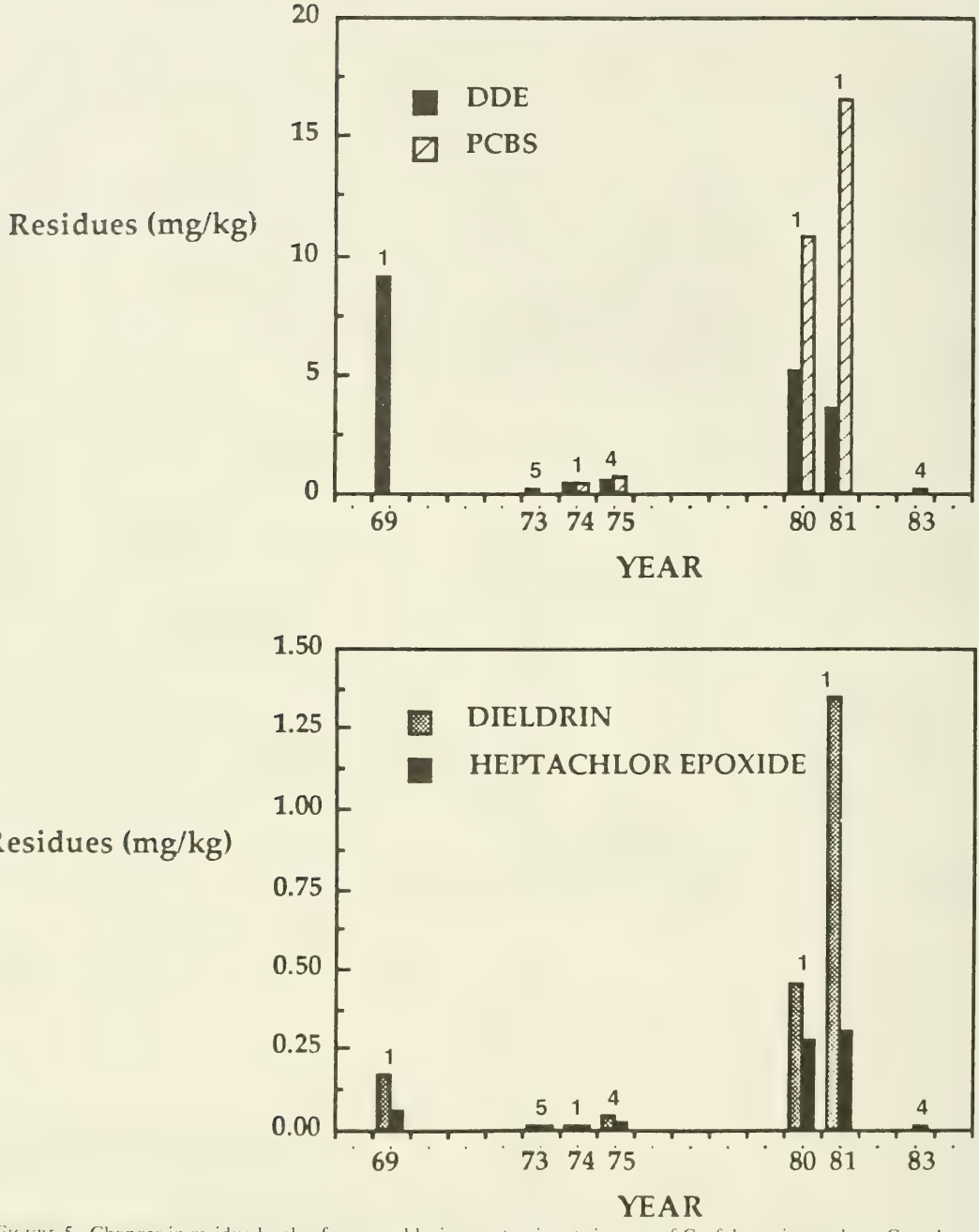

FIGURE 5. Changes in residue levels of organochlorine contaminants in eggs of Gryfalcons in northern Canada.

nants could be discerned, although DDE, PCBs, heptachlor epoxide were highest in 1980 and 1981 (Figure 5).

There were insufficient data from Atlantic Canada or British Columbia to permit analyses of temporal trends. Although raptors have been used to monitor changes in environmental levels of persistent contaminants elsewhere (e.g. Froslie et al. 1986), the extreme variability in both eggs and tissue levels due to individual and geographic differences in diet, migratory behaviour and exposure, makes it difficult to discern trends. From the sparse temporal data available, we can conclude only that dieldrin and DDE occurred at

lower levels in Prairie raptors in the 1980s than during the early 1970s. Heptachlor epoxide levels have remained at low levels, except in a few individuals.

The status of raptor populations in Canada

The status of raptor populations in Canada is not well known, despite increasing interest in their welfare. The main sources of data on population trends come from counts along migration routes, Christmas Bird Counts, Breeding Bird Surveys, and research programs aimed at determining the status of particular species.

Counts of most raptors are made annually during migration at a number of locations in North America, where movements of migrants are restricted by large bodies of water or mountain ranges (Heintzelman 1986). Of the more than one hundred such sites, Hawk Mountain, Pennsylvania, and Point Cape May, New Jersey, are the longest in operation. In the Great Lakes region, migrating raptors are monitored in Beamer and at Hawk Cliff (Ontario), Derby Hill (New York), and Duluth and Whitefish Point (Michigan). Data from these counts can be used to determine trends if certain assumptions (such as no overall changes in migratory paths) are made, and if weather and observer effort data are standardized (Sattler and Bart 1984).

Long-term trends can also be estimated from Breeding Bird Surveys, an ongoing census of birds breeding along selected transects all over North America (Robbins et al. 1986). Other status assessments are derived from research employing a variety of census techniques ranging from aerial surveys of Bald Eagles (Gerrard and Ingraham 1985) to detailed investigations of breeding success (e.g. Fox 1971). Nevertheless, the status of many species inhabiting remote areas, or whose nests are difficult to locate, has not been established.

All methods of estimating numbers are subject to bias, and hence require cautious interpretation (Bock and Root 1981; Fuller and Mosher 1987). Table 3 summarizes the reported status of North American raptor populations, according to a number of reviews. Blue Lists are subjectively based on the opinions of experienced raptor enthusiasts from different regions (Tate 1986). Henny's (1972) assessments were based on the modelling of banding recovery data and estimated reproductive parameters. The results of counts of migrating raptors (Heintzelman 1986) and Breeding Bird Surveys (Robbins et al. 1986) are influenced by many factors, particularly weather and observer differences. However, as the biases inherent in the techniques employed to obtain these estimates are independent of each other, we feel that a consistent status assessment for a particular species can be considered to be accurate.

We used the sources listed in Table 3, as well as the available literature on the status of particular species or populations (Noble and Elliott *in press*) in order to assign each species to one of four categories.

The first group comprises species which are known to have experienced declines during the era of extensive pesticide use. It includes Bald Eagle populations in Ontario (Postupalsky 1971; Grier 1982) and the Maritimes (Stocek and Pearce 1978), Osprey in Ontario (Posupalsky 1972), Cooper's Hawk (Penak 1981), Merlins (Fox 1971; DeSmet 1985), Prairie Falcons (Fyfe et al. 1976) and Peregrine Falcons (Peakall 1976).

Numbers of some of these species have recovered; others are still reduced. Gerrard and Ingraham (1985) noted that most Bald Eagle populations in Canada were stable or increasing, although they are still very rare in the Great Lakes. Ospreys apparently did not experience the dramatic declines noted in the United States, but in Nova Scotia, at least, it appears that productivity has increased since the mid 1970s (Fleming, personal communication). Although the extent and timing of population declines of Merlins in the Prairies has been debated (DeSmet 1985), productivity and numbers do appear to have increased in recent years. Determining the effects of pesticides on Cooper's and Sharp-shinned Hawks is also problematic, as the evidence for declines in Canada is equivicol (Flood and Bortolotti 1986), despite the dramatic declines reported in the United States (Henny and Wight 1972; Snyder et al. 1973). Extensive shooting of these species in the 1950s and 1960s is one complicating factor; an ability to compensate for high mortality by increased productivity early in life is another possibility.

The second category comprises species which are currently in decline, whether or not numbers are known to have declined in the past. Canadian raptors in this group include Red-shouldered Hawks (Risley 1983), Ferruginous Hawks (Schmutz and Schmutz 1980), Barn Owls (Campbell and Campbell 1983), Short-eared Owls and Burrowing Owls (Wedgewood 1978).

The third category is comprised of species whose numbers have always been stable, or which appear to be increasing over most of their range. These include Red-tailed Hawks, Turkey Vultures and Great Horned Owls (*see* Table 3).

The last category includes species for which there is no consistent evidence of either declines or increases (Table 3). These include most of the boreal forest owls, Golden Eagles, Northern Harriers, Gyrfalcons (Martin 1978), Northern

TABLE 3. Status of North American raptor populations based on different sources.

Source:	Henny 1972	Fyfe 1976	Robbins et al. 1982	Heintzelman 1986	Blue List
Time period:	1946-68	1975	1965-79	1961-84	1980s
Sharp-shinned Hawk		stable decline in Ontario	stable	increase (1977-84)	declining?
Cooper's Hawk	declining	stable decline in Ontario	stable	increase (1975-84)	stable
Northern Goshawk		cyclic		cyclic	
Red-tailed Hawk	stable	stable	increasing	stable	
Red-shouldered Hawk	declining	declining	stable	declining?	declining
Broad-winged Hawk		stable	stable	stable	
Rough-legged Hawk		fluctuating		cyclic	
Ferruginous Hawk		stable			declining?
Swainson's Hawk		declining			stable?
Bald Eagle		stable declining in Ontario		increase (1975-84)	
Golden Eagle		stable		declining	stable
Osprey	declining	stable	increase (east) declining (west)	stable	increase
Northern Harrier		fluctuating decline in Alberta	declining	stable	
Turkey Vulture			stable		
Peregrine Falcon		declining		declining (1972-84)	
Prairie Falcon		stable in prairies decline in British Columbia			
Merlin		stable decline in Ontario		declining	
American Kestrel	declining (1960-70)	stable increase in British Columbia		cyclic	
Gyrfalcon		stable			
Great Horned Owl		stable increase in Ontario	stable		
Short-eared Owl		fluctuating			declining
Long-eared Owl		fluctuating			
Barn Owl	stable?				declining?
Burrowing Owl		stable	declining		declining?
Great Grey Owl		fluctuating			
Snowy Owl		fluctuating			
Saw-whet Owl		stable			

Goshawks, Rough-legged Hawks and Broad-winged Hawks, *Buteo platypterus*. Sharp-shinned Hawks were still blue-listed in some areas, but other populations were apparently healthy (Tate and Tate 1981; Tate 1986).

There are many possible causes of raptor population declines, not the least of which is shooting, an activity that was prevalent until the 1960s. Other factors include loss of nesting habitat, reductions in prey abundance, disturbance of breeding sites, competition, and poisoning by currently used insecticides and rodenticides.

Examination of the species in each category reveals some within-group similarities. Species in the first category which exhibited the most dramatic declines in the late 1960s, feed primarily on birds or fish. The relatively high levels of organochlorines found in migratory birds compared to mammals has been well documented (Enderson and Berger 1970; Snyder et al. 1973). Since restrictions on the use of most organochlorine pesticides and mercurials in North America in the early 1970s, many of the species in this category have shown evidence of recovery (Grier 1982; Tate 1986; James et al. 1987).

Although some species in the second category also feed on birds, most are species with relatively specialized habitat requirements. Reduced

numbers of Red-shouldered Hawks in Ontario have been attributed mainly to loss of riparian deciduous forests (Risley 1983). In western Canada, the deterioration and loss of natural prairie and its replacement with crops and forage has undoubtedly contributed to declines in Ferruginous Hawks (Schmutz and Schmutz 1980) and the Burrowing Owl (Wedgewood 1978).

Species in the third category tend to adapt well to human activities, profiting from new sources of food, or utilizing anthropogenic nest sites. Species such as the Red-tailed Hawk may have benefited by the reduced numbers of its competitors (Runyan 1988).

The fourth category includes most of the arctic species, for which little population data are available, and which have probably not been affected by changes in habitat. Numbers of Northern Harriers, Gyrfalcons and Rough-legged Hawks tend to fluctuate according to the abundance of their preferred prey; voles (Duncan 1986), ptarmigan (Martin 1978) and lemmings (Godfrey 1986), respectively, and are therefore difficult to census. In species such as the American Kestrel, the negative impact of exposure to agricultural chemicals may have been mitigated by the increase in suitable open habitat and the increased availability of nest boxes.

Conclusions

Some Canadian raptors continue to be exposed to potentially toxic levels of organochlorines. Species such as Merlins, Peregrine Falcons, Sharp-shinned and Cooper's hawks which feed mainly on migratory birds are most contaminated. Reliable evidence of reproductive effects in Canadian raptors is restricted to a few species, namely Bald Eagles, Merlins, Peregrine Falcons and Prairie Falcons. However, high concentrations of DDE in eggs of those species as well as Osprey and Sharp-shinned and Cooper's hawks, were probably responsible for significant eggshell thinning and reduced productivity in the late 1960s and early 1970s. Most owls and buteos, Golden Eagles, Gyrfalcons and American Kestrels are unlikely to have been affected by DDE.

A few individuals and eggs of a number of species were found to contain significant concentrations of dieldrin, heptachlor epoxide or oxychlordane. There was no evidence that mercury has had any detrimental impact on Canadian raptors, although elevated concentrations were found in the livers of one Bald Eagle and several Turkey Vultures.

Since the restrictions on the use of DDT and dieldrin were implemented in the early 1970s, concentrations detected in raptor eggs have generally declined. Populations of greatly reduced species (e.g. Bald Eagles in southern Ontario, Peregrine Falcons in eastern Canada) aided by reintroduction programs are showing signs of recovery, and there is some evidence to suggest that Merlins, Prairie Falcons, Osprey and Cooper's Hawk numbers have increased since the last decade. Declines in other species such as Ferruginous Hawks, Barn Owls and Red-shouldered Hawks have been reported more recently, and have been largely attributed to deterioration and loss of habitat.

Nevertheless, the continued prevalence of organochlorine contaminants in the body tissues and eggs of Canadian raptors years after most of the parent compounds were banned suggests that we should continue to monitor them closely, particularly those feeding on migratory birds. Although we did not detect an effect of wintering area on contaminant concentrations, pesticide use in some Latin American countries where several Canadian raptors and their migratory prey species overwinter, may be a contributing source of current exposure.

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APPENDIX 1A. Concentrations of organochlorines in tissues of Canadian raptors between 1967 and 1985.

Species and year	Prov.	Tissue	N	Mean residue levels (mg/kg, wet weight)					
				DDE	Dieldrin	HE	Oxychlordane	HCB	PCBS
Sharp-shinned Hawk									
1969	B.C.	Brain	1	0.35	0.043				
1982-85	B.C.	Livers	7	3.62	0.128	0.095	0.17	0.044	3.51
Cooper's Hawk									
1967	B.C.	Brain	1	0.58	0.013				
1984-85	B.C.	Livers	3	12.3	0.63	0.32	0.48	0.012	4.77
Red-tailed Hawk									
1967	Sask.	Brain	2	0.068	0.075	0.016			
1968	Alta.	Brain	1	0.47	0.15	0.057			
1968	B.C.	Brain	1	0.39	0.013				
Swainson's Hawk									
1968	Sask.	Brain	4	0.085	0.19	0.131			
1968-71	Alta.	Brain	5	0.058	0.041	0.048			
Ferruginous Hawk									
1969	Sask.	Brain	1	0.12	0.013	0.85			
1971	Alta.	Whole body	2	0.050	0.027	0.077			
Rough-legged Hawk									
1973	Yukon	Brain	3	0.21	0.014	0.001		0.010	0.61
		Liver	3	0.074	0.007	0.002		0.007	0.21
1974	N.W.T.	Liver	1	0.13	0.020	0.010		0.020	1.13
Bald Eagle									
1970	N.B.	Brain	1	7.09	0.18	0.062		0.005	
1969	Man.	Brain	1	0.53	0.045	0.009			
		Liver	1	2.12	0.11	0.017			
1968	B.C.	Brain	1	6.22	0.10				
Golden Eagle									
1973	N.W.T.	Brain	2	0.21	0.010	0.002		0.007	0.57
		Liver	2	0.28	0.007	0.001		0.010	0.54
Osprey									
1969	Ont.	Brain	1	0.22	0.013			0.017	
		Liver	1	0.22	0.021			0.012	
1971	Ont.	Brain	1	0.10	0.020				
		Liver	1	0.54					
Northern Harrier									
1968	Sask.	Brain	3	0.039	0.007	0.030			
1968	B.C.	Brain	1	0.55	0.048				
Gyrfalcon									
1968	N.W.T.	Liver	1	0.040	0.001	0.001		0.005	0.14
1971	B.C.	Brain	1	0.58	0	0		0.030	
		Liver	1	0.80	0.010			0.014	
Merlin									
1969	Alta.	Brain	1	0.23	0.017	0.014			
1969	Alta.	Brain	1	0.29	0.068	0.18			
1972	Alta.	Brain	1	0.070	0.010				
		Liver	1	0.11	0.060	0.030			
1973	Alta.	Brain	2	1.09	0.035	0.010		0.010	1.87
		Liver	2	3.16	0.079	0.049		0.025	1.56
1968	B.C.	Brain	1	15.8	0.38	0.22			
American Kestrel									
1968	Alta.	Brain	1	0.26	0.017	0.062			
1968	Alta.	Brain	1	0.079	0.009	0.020			
Prairie Falcon									
1973	Alta.	Brain	1	0.36	0.020	0.020		0.010	0.75
		Liver	1	0.34	0.010	0.020		0.010	0.29
1969	Alta.	Brain	1	0.095	0.014	0.007			
1969	Alta.	Brain	1	0.377	0.033	0.18			
		Liver	1	0.28	0.056	0.43			
1972	Alta.	Brain	3	0.13	0.016	0.060		0.010	
		Liver	3	0.33	0.023	0.19		0.010	
1975	Alta.	Brain	1	1.97	0.080	0.11		0.020	0.31
		Liver	1	4.50	0.13	0.13		0.030	0.54
1975	Alta.	Brain	1	0.15	0.005	0.005		0.010	0.57
		Liver	1	0.030	0.001	0.001		0.005	0.18
1976	Alta.	Brain	1	0.42	0.040	0.090	0.010	0.005	0.44
		Liver	1	0.84	0.090	0.35	0.030	0.010	0.80
1976	Alta.	Brain	7	0.43	0.040	0.16	0.011	0.007	0.13
		Liver	7	1.58	0.12	0.55	0.069	0.030	0.74

APPENDIX 1A. *Concluded*

Species and year	Prov.	Tissue	N	Mean residue levels (mg/kg, wet weight) DDE	Dieldrin	HE	Oxychlordane	HCB	PCBS
1977	Alta.	Brain	1	0.73	0.020	0.060	0.001	0.020	0.35
		Liver	1	0.94	0.060	0.21		0.020	0.51
Barn Owl									
1984-85	B.C.	Liver	8	0.55	0.033	0.037	0.057	0.006	0.48
Great Horned Owl									
1969	N.B.	Brain	2	0.18	0.003				
1967	Sask.	Brain	1	0.21	0.023	0.010			
1969	Sask.	Brain	1	0.039	0.003	0.006			
1970	Sask.	Liver	1	0.74	0.097	0.17			
1984	Alta.	Liver	2	14.8	0.32	0.79	0.39	0.30	12.5
Burrowing Owl									
1968	Alta.-Sask.	Brain	3	1.08	0.019	0.092			
Long-eared Owl									
1967	Sask.	Brain	1	0.14	0.022				
Short-eared Owl									
1968	B.C.	Brain	3	0.060	0.004				

N = maximum number of anayses per compound.

APPENDIX 1B. Mercury concentrations (mg/kg, wet weight) in livers of raptors collected in Canada between 1968 and 1976.

Species	Years	Province/ Territory	No.	Mercury
Swainson's Hawk	1968	Saskatchewan	7	0.36
	1968-71	Alberta	10	0.16
Red-tailed Hawk	1968	Alberta	1	0.48
Ferruginous Hawk	1969	Saskatchewan	1	0.18
	1971	Alberta	8	0.020
Rough-legged Hawk	1974	N.W.T.	1	0.030
Balt Eagle	1970	Ontario	2	30.5
Osprey	1969	Ontario	1	3.1
	1971	Ontario	1N	0.68
Northern Harrier	1968	Saskatchewan	3	0.057
Turkey Vulture	1970	Ontario	2	30.8
Merlin	1969	Alberta	1	0.084
	1971	Alberta	2	0.050
	1972	Alberta	1	0.040
Prairie Falcon	1969	Alberta	1N	0.15
	1969	Alberta	1	1.26
	1972	Alberta	2N	0.024
	1975	Alberta	1	0.11
	1975	Alberta	1	0.020
	1976	Alberta	1	0.42
	1976	Alberta	3	0.022
Gyrfalcon	1971	B.C.	1	0.68
American Kestrel	1968	Alberta	1	0.74
	1968	Alberta	1	0.46
Great Horned Owl	1968	Ontario	1	1.44
Burrowing Owl	1968	Saskatchewan	3	1.7
Short-eared Owl	1968	Alberta	3	3.4

N = nestling

APPENDIX 2A. Residue levels of environmental contaminants detected in eggs of accipiters in Canada (geometric means with range in parentheses)

Region	Years	N	Organochlorine residue levels (mg/kg, wet weight)						Mercury
			DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	
Sharp-shinned Hawk									
Prairies	1965-72	1	7.0	0.12	0.057				0.12
Ontario	1980-88	9	8.2	0.27	0.19	0.20	0.021	2.1	
			(3.52-18.6)	(0.088-1.19)	(0.084-0.82)	(0.020-0.88)	(.0095-0.057)	(1.5-3.7)	
Atlantic	1980-88	3	7.0	0.53	0.34	0.76	0.041	4.24	
			(5.42-9.12)	(0.39-0.75)	(0.30-0.41)	(0.67-0.85)	(0.025-0.062)	(3.52-4.87)	
Cooper's Hawk									
Prairies	1965-72	17	3.8	0.17	0.096		0.009		0.085
			(2.35-14.6)	(0.035-5.87)	(0.012-0.56)		(ND-0.057)		(0.040-0.13)
Prairies	1973-79	3	5.06	0.24	0.076	0.060	0.032	2.2	0.035
			(3.91-5.95)	(0.10-1.31)	(0.03-0.16)	(0.020-0.057)	(0.64-7.72)	(0.03-0.040)	
Ontario	1980-88	13	4.61	0.30	0.16	0.23	0.009	1.97	
			(1.19-25.3)	(0.066-0.69)	(0.029-1.0)	(0.028-1.6)	(0.003-0.026)	(0.66-9.23)	
Northern Goshawk									
Atlantic	1965-72	1	3.9	0.049	0.019				
Ontario	1980-88	4	0.99	0.089	0.041	0.064	0.004	0.56	
			(0.27-1.8)	(0.036-0.20)	(0.021-0.079)	(0.038-0.11)	(0.002-0.007)	(0.24-0.88)	

ND = nondetectable (not included in mean); N = maximum number of analyses per compound.

APPENDIX 2B. Residue levels of environmental contaminants detected in eggs of buteos in Canada (geometric means with range in parentheses).

Region	Years	N	Organochlorine residue levels (mg/kg, wet weight)						Mercury
			DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	
Red-tailed Hawk									
Prairies	1965-72	46	1.22	0.36	0.092				0.099
			(0.29-16.4)	(0.033-5.9)	(0.004-2.55)				(0.023-0.36)
Ontario	1965-72	2	0.48	0.17	0.018		0.038		0.089
					(0.015-0.021)		(0.035-0.042)		(0.080-0.010)
B.C.	1965-72	1	4.72	0.26	0.11				
Red-shouldered Hawk									
Ontario	1973-79	3	2.4	0.18	0.046		0.015	1.88	
			(1.4-3.78)	(0.08-0.42)	(0.03-0.08)		(0.0095-0.019)	(1.05-3.11)	
Swainson's Hawk									
Prairies	1965-72	18	0.63	0.34	0.22				0.092
			(0.092-5.92)	(0.021-1.25)	(0.063-4.08)				(0.03-0.42)
Prairies	1973-79	1	0.66	0.080	0.030		0.019		0.16
Prairies	1980-88	8p	0.39	0.050	0.12	0.025	0.021	0.15	
			(0.83-1.02)	(0.014-0.19)	(0.029-0.29)	(0.01-0.036)	(0.004-0.129)	(0.022-0.49)	
Ferruginous Hawk									
Prairies	1965-72	50	0.28	0.085	0.14		0.010		0.035
			(0.030-13.1)	(0.010-4.3)	(0.02-2.3)		(ND-0.010)		(0.010-0.25)
Prairies	1980-88	1p	0.053	0.047	0.085	0.024	0.003	0.21	
Prairies	1980-88	1p	0.15	0.050	0.14	0.019	0.011	0.17	
Rough-legged Hawk									
North	1965-72	13	0.40	0.092	0.049		0.010		0.15
			(0.10-2.35)	(0.007-0.29)	(0.04-0.074)		(ND-0.01)		(0.045-0.32)
North	1973-79	1	0.46	0.050	0.030		0.019		
North	1980-88	6	0.33	0.032	0.22	0.040	0.042	1.32	0.053
			(0.03-1.19)	(0.01-0.14)	(0.005-2.69)	(0.01-0.19)	(0.01-0.61)	(0.27-5.08)	(0.04-0.07)

ND = nondetectable (not included in mean); p = pooled sample; N = maximum number of analyses per compound.

APPENDIX 2C. Residue levels of environmental contaminants detected in eggs of eagles, ospreys and harriers in Canada (geometric means with range in parentheses).

			Organochlorine residue levels (mg/kg, wet weight)						
Region	Years	N	DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	Mercury
Bald Eagle									
Atlantic	1965-72	1	23.1	0.53			0.020		0.24
Atlantic	1980-88	2	2.31				0.025	8.11	
			(1.03-4.84)				(0.019-0.032)	(4.22-15.6)	
Ontario	1965-72	16	33.4	1.27	0.23		0.056		0.39
			(17.8-99.3)	(0.59-2.87)	(0.04-0.68)		(0.01-0.16)		(0.19-0.73)
Ontario	1973-79	2	33.8	0.85	0.052	0.108	0.29	18.7	0.24
			(32.0-35.8)	(0.56-1.29)	(0.03-0.09)	(0.036-0.32)	(0.27-0.32)	(17.3-20.4)	(0.18-0.31)
Prairies	1965-72	13	4.11	0.21	0.017		0.011		0.11
			(1.37-28.5)	(0.033-1.06)	(ND-0.12)		(0.004-0.030)		0.06-2.62)
Golden Eagle									
Prairies	1965-72	9	0.77	0.14	0.12		0.010		0.043
			(0.29-2.81)	(0.06-0.56)	(0.02-0.85)		(ND-0.01)		(0.02-0.22)
Prairies	1973-79	13	0.69	0.10	0.069		0.014	0.82	0.038
			(0.08-2.05)	(0.01-2.12)	(0.01-0.89)		(ND-0.038)	(0.95-3.6)	(0.01-0.34)
Osprey									
Atlantic	1965-72	3	6.17	0.010			0.010		0.097
			(5.67-7.15)	(ND-0.01)			(ND-0.01)		(0.07-0.13)
Ontario	1965-72	8	3.9	0.062	0.050		0.016		0.098
			(1.71-9.61)	(0.01-0.31)	(ND-0.05)		(ND-0.02)		(0.06-0.23)
Prairies	1973-79	4	14.3	0.079	0.049		0.019	0.94	0.36
			(2.3-24.0)	(0.03-0.33)	(0.03-0.08)		(0.009-0.038)	(0.72-1.24)	(0.04-0.79)
B.C.	1965-72	2	4.5	0.009	0.017				
			(3.37-6.11)	(0.005-0.017)	(0.014-0.020)				
Northern Harrier									
Atlantic	1965-72	1	14.5	0.99	0.069				
Prairies	1965-72	22	1.41	0.27	0.11				0.044
			(0.013-20.4)	(0.010-5.2)	0.016-1.56				(0.014-0.060)

ND = nondetectable (not included in mean); N = maximum number of analyses per compound.

APPENDIX 2D. Residue levels of environmental contaminants detected in eggs of falcons in Canada (geometric means with range in parentheses).

			Organochlorine residue levels (mg/kg, wet weight)						
Region	Years	N	DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	Mercury
Merlin									
B.C.	1965-72	1	8.38	0.20	0.43				0.52
Prairies	1965-72	125*	6.75	0.33	0.33		0.026		0.18
			(1.13-17.4)	(0.029-3.24)	(0.04-5.40)		(0.008-1.84)		(0.04-1.29)
Prairies	1973-79	109*	9.66	0.24	0.50	0.17	0.056	1.18	0.046
			(0.24-90.9)	(0.005-4.3)	(0.005-6.16)	(0.09-1.314)	(0.009-3.287)	(0.22-4.28)	(0.01-0.56)
Prairies	1980-88	14	2.95	0.042	0.29	0.028	0.014	0.24	
			(0.27-6.6)	(0.007-0.59)	(0.065-2.03)	(0.031-0.26)	(0.13-0.31)		
North	1965-72	1	33.2	0.23	0.082		0.003		0.72
North	1973-79	4	16.5	0.95	0.29		0.047	1.30	0.073
			(10.7-19.7)	(0.42-2.64)	(0.18-0.55)		(0.03-0.08)		(0.01-0.34)
Prairie Falcon									
Prairies	1965-72	249	1.83	0.14	0.29		0.024		0.086
			(0.14-31.4)	(0.005-4.45)	(0.03-7.04)		(0.004-0.41)		(0.01-1.22)
Prairies	1973-79	216	1.7	0.099	0.21	0.052	0.036	0.74	0.017
			(0.08-33.4)	(0.005-7.20)	(0.005-2.43)	(0.009-0.43)	(0.009-1.42)	(0.10-9.57)	(0.005-0.38)
Prairies	1980-88	16	0.38	0.060	0.076	0.024	0.048	0.25	
			(0.41-1.63)	(0.002-1.05)	(0.013-0.76)	(0.007-0.07)	(0.008-0.35)	(0.036-0.93)	
Prairies	1988	pool of 9	0.056	0.002	0.012	0.004	0.11	0.072	
		pool of 5	0.041	0.002	0.009	0.003	0.010	0.15	
Gyrfalcon									
North	1965-72	1	9.02	0.17	0.057		0.020		1.43
North	1973-79	10	0.33	0.016	0.016		0.014	0.59	0.009
			(0.07-0.57)	(0.005-0.04)	(0.005-0.03)		(0.005-0.038)	(0.04-0.77)	(ND-0.03)
North	1980-88	6	0.12	0.018	0.028	0.031	0.069	0.47	2.20
			(0.014-5.1)	(0.001-1.34)	(0.006-0.30)	(0.005-0.45)	(0.011-0.90)	(0.033-16.5)	

APPENDIX 2D. *Concluded*

Region	Years	N	Organochlorine residue levels (mg/kg, wet weight) DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	Mercury
American Kestrel									
Atlantic	1965-72	1	12.4	0.44					
Prairies	1965-72	8	1.9 (0.60-11.9)	0.038 (0.002-1.25)	0.51 (0.034-4.79)				0.23 (0.16-0.29)
South Ontario	1987	17p	10.8	0.077	0.11	0.11	0.022	0.86	
Central Ontario	1987	9p	0.44	0.013	0.009	0.027	0.017	0.18	
North Ontario	1987	5p	2.7	0.081	0.078	0.061	0.007	0.35	
South Ontario	1988	10p	3.8	0.042	0.043	0.051	0.007	0.32	
Central Ontario	1988	9p	0.43	0.066	0.039	0.038	0.005	0.16	

ND = nondetectable (not included in mean); p = pooled sample; N = maximum number of analyses per compound; *fresh eggs only.

APPENDIX 2E. Residue levels of environmental contaminants in eggs of owls in Canada (geometric means with range in parentheses).

Region	Years	N	Organochlorine residue levels (mg/kg, wet weight) DDE	Dieldrin	HE	Oxychlordane	HCB	PCBs	Mercury
Great Horned Owl									
Prairies	1965-72	30	2.23 (0.073-16.2)	0.090 (0.011-0.76)	0.11 (ND-1.88)		0.017 (ND-0.017)		0.063 (0.070-0.12)
Ontario	1965-72	1	0.85	0.2					
North	1965-72	1	1.52	0.10	0.25				
Snowy Owl									
North	1973-79	1	3.27	0.14	0.15		0.11		0.11
Burrowing Owl									
Prairies	1965-72	1	0.67	0.42	0.15				0.11
Great Grey Owl									
Minnesota	1980-88	3	0.059 (0.04-0.10)	0.014 (0.01-0.02)	0.010 (0.01-0.01)	0.014 (0.01-0.03)	0.005 (0.004-0.007)	0.12 (ND-0.12)	
Long-eared Owl									
Prairies	1965-72	7	0.60 (0.078-3.06)	0.014 (0.005-0.15)	0.010 (0.005-0.018)				0.036 (0.025-0.046)
Short-eared Owl									
Prairies	1965-72	6	4.07 (2.14-7.64)	0.099 (0.025-0.94)	0.037 (0.016-0.11)				

ND = nondetectable (not included in mean); N = maximum number of analyses per compound.

Environmental Contaminants in Canadian Peregrine Falcons, *Falco peregrinus*: A Toxicological Assessment

DAVID B. PEAKALL[1], DAVID G. NOBLE[1], JOHN E. ELLIOTT[2], JAMES D. SOMERS[3], and GARY ERICKSON[4]

[1]National Wildlife Research Center, Canadian Wildlife Service, Ottawa, Ontario K1A 0H3
[2]Canadian Wildlife Service, Pacific and Yukon Region, Delta, British Columbia V4K 3Y3
[3]Alberta Environmental Centre, Vegreville, Alberta T0B 4L0
[4]Alberta Forestry, Lands and Wildlife, Edmonton, Alberta T5K 2G6

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The organochlorine residue levels in 205 eggs and 62 tissues samples from 28 specimens of the Peregrine Falcon collected in Canada over the period 1965-1987 are presented. The data are grouped in three time periods — 1965-1972, 1973-1979 and 1980-1987 — representing, respectively, the organochlorine era in North America, the immediate post-restriction era and the current period. The toxicological data available are reviewed to define the critical levels of the individual organochlorines to raptorial species. The residues found in the Peregrine are assessed against the critical levels. In all three subspecies the proportion of specimens having residue levels above the critical values has decreased and can be correlated with improvements in the reproductive success of the population.

Les niveaux de substances organochlorées provenant de 205 oeufs et 62 tissus de faucons pèlerins échantillones au Canada entre 1965 et 1987 sont présentés. Les données sont regroupees dans le temps selon trois périodes — 1965-1972, 1973-1979 et 1980-1987 — représentant, dans cet ordre, l'époque d'utilisation des organochlorés en Amérique du nord, l'époque actuelle. Les données toxicologiques sont évaluées afin d'établir les niveaux critiques chez les falconiformes pour chaque substance organochlorée. Les concentrations trouvées chez le faucon pèlerin sont ainsi évaluées en fonction de ces niveaux critiques. Pour chacune des trois sous-espèces la proportion des échantillons avec des concentrations supérieures aux valeurs critiques a diminué et ceci peut etre relié a l'amélioration du succès reproductif de ces populations.

Key Words: Peregrine Falcon, *Falco peregrinus*, toxicology, organochlorines, reproduction.

Peregrine Falcon (*Falco peregrinus*) populations have been a focus of environmental concern since widespread declines were first revealed at an international conference on the Peregrine Falcon in 1965 (Hickey 1969). Eggshell thinning was discovered in the peregrine at about that time (Ratcliffe 1967) and soon afterwards critical levels were established for a number of other species (Hickey and Anderson 1968). DDE-induced eggshell thinning has been considered as a primary cause of the declines of the peregrine (Peakall 1976; Risebrough and Peakall 1988). Direct mortality from another insecticide, dieldrin, was also a factor in the United Kingdom (Ratcliffe 1980; Nisbet 1988). The slow recovery of Peregrine Falcon populations in Canada, especially in the east, has been blamed largely on the continuing high levels of DDE in peregrine eggs, presumably from exposure on their Latin American wintering grounds or from feeding on migratory prey.

The main purposes of this paper are: (1) to summarize the data on levels of environmental contaminants in tissues and eggs of Peregrine Falcons in Canada from the earliest collections to the present time; (2) to evaluate the biological effects of observed levels of DDE and other toxic substances in peregrines; (3) to determine temporal trends and geographical differences in levels of contaminants and, where possible, to relate these to patterns of pesticide use and migratory patterns of the peregrine and their prey.

The important question from a conservation viewpoint is whether peregrine populations are currently being adversely affected by environmental contaminants. This information is vital to the selection of release sites and the decision whether or not to manipulate populations artificially. Through extensive manipulations, including replacing wild-laid eggs with captive-laid eggs and hacking young, it is possible to maintain polluted populations (Walton et al. 1988).

Races of Peregrines

The three races of peregrines found in North America have widely different migratory habits which effect markedly their exposure to pesticides. The breeding ranges and migratory routes are discussed elsewhere in this volume (White et al. 1990).

TABLE 1. Summary of Peregrine Falcon eggs and tissues analysed for organochlorines and mercury.

		65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	Total
Falco peregrinus pealei																									
Langara Is., B.C.	Eggs	2		2		4	2	1	1														4		16
	Tissue		2(1)			6(2)																			8(3)
Falco peregrinus anatum																									
Eastern Canada	Eggs						1															3	1*	2**	7
	Tissue					3(1)														4(1)			2(1)		9(3)
Alberta	Eggs				1				4		5			3	5	7	3	6	7	5	7	11	7	12	82
	Tissue			1(1)					1(1)	2(1)															4(3)
Yukon	Eggs					3			3	3					1		6	3							19
NWT	Eggs									4			6	1			1	2							14
Mackenzie R.	Tissue					2(1)																			2(1)
Falco peregrinus tundrius																									
Ungava Bay	Eggs			10		1						4									7		3		25
Quebec	Tissue			9(8)																					9(8)
NWT	Eggs		4	1	6	4				1	3		3				6	7	3						41
	Tissue		10(2)			10(5)					8(2)							4(2)							32(11)
TOTAL	Eggs	2	4	13	7	12	3	1	9	10	5	7	9	4	6	7	16	18	8	7	14	14	15	14	205
	Tissue		12	10		21			1	2	8							4		4					62
	Specimens		3	9		9			1	1	2							2		1					28

Tissue: Number of analyses performed (number of specimens); *pool of four eggs; **pool of nine eggs.

Peale's Peregrine (*F. p. pealei*) is a maritime resident which breeds in the Queen Charlotte Islands of British Columbia, southern Alaska and the Aleutians (Beebe 1974). The Arctic Peregrine (*F. p. tundrius*) breeds in the tundra regions of Canada, Alaska and Greenland north of the tree line. The main breeding areas include southern Baffin Island, Ungava Bay, western Hudson Bay, the central Arctic coast, and the interior barrens of the Northwest Territories (White 1968). The American Peregrine (*F. p. anatum*) breeds or bred in forested areas from the tree line south to California and Mexico (Cade 1982).

Collections

The specimens for which residue data are available to us are listed in Table 1. Some of the pre-1973 data have been reported previously. Gilbertson and Reynolds (1974) summarized the DDE and PCB data on peregrines in Canada; Berger et al. (1970) reported data for Ungava Bay; Enderson and Berger (1968) for northern Alberta and the Northwest Territories and Nelson and Myers (1977) for British Columbia. Residue analysis samples material from Rankin Inlet are reported elsewhere (Court et al. 1990).

Most samples were eggs. These were often unhatched and were collected during banding or after the nesting season, although the material from Alberta was largely collected earlier in the nesting season. A number of adults and nestlings collected, or found dead, were also analyzed for organochlorine (OC) content. Tissues analyzed most frequently were breast muscle, brain and liver.

Analyses of material collected before 1984 were carried out by the Ontario Research Foundation (Reynolds and Cooper 1975). Material from Alberta was analyzed at the Alberta Agriculture and Food Laboratory prior to 1984 and a private laboratory thereafter. The technique used followed the Analytical Methods Manual of the Inland Waters Directorate (Environment Canada, 1974). The remainder of the analyses were carried out at the National Wildlife Research Centre (Peakall et al. 1986). Intercalibration between the two laboratories was maintained by a check sample program using the CWS pooled gull egg homogenate.

All residue levels are reported as mg/kg wet weight of the sample. The mean water content of peregrine eggs listed as "fresh" was 80.4% with 95% of values falling within the range of 76.8 to 83.4%. When the recorded moisture was outside this range the residue levels were corrected using the mean value. When corrected for moisture loss, no significant differences were found for the residue levels recorded from addled or fresh eggs.

Since the raw data was not normally disturbed, all values were transformed to common logarithms, and all subsequent analyses were carried out on the transformed data. Summarized data are presented as geometric means and range.

Geographical differences within defined time periods were tested for using the Student-Newman-Keuls multiple range test in the ANOVA procedures of SAS (SAS Institute Inc. 1988). Temporal trends of residue levels were investigated by regression analysis using the General Linear Models procedure of SAS (SAS Institute Inc. 1988).

Feeding Ecology

The vulnerability of the peregrine to organochlorines results from its position as a terminal predator. The main prey of peregrines are birds, primarily passerines, waterfowl, shorebirds and gulls. However, almost all species of birds and many small mammals have been recorded as prey. The *F. p. pealei* in the Queen Charlottes specializes on small alcids like the Ancient Murrelet (*Synthliboramphus antiquum*) (Nelson and Myres 1977). In northern Alberta, the main species taken were small gulls, nighthawks, flickers, coots and other waterfowl (Johnson-Beaver, 1979). Farther north, in the Campbell Hills, main prey items were waterfowl, but also included yellowlegs and gulls (NPRT 1988). In Alaska the *tundrius* race feeds to a large extent on passerines, ptarmigan and shorebirds (Cade 1960), but at Rankin Inlet, NWT, mammals were also an important part of the diet (Court et al. 1988). A wide range of prey is taken by peregrines on their breeding grounds, during migration and in the wintering areas. There is considerable individual variation and specialization. The residue levels in prey species are considered elsewhere (Baril et al 1990; Fyfe et al. 1990).

Effects of Contaminants

The objective of this section is to review the toxicological data available on raptors and define as closely as possible the "critical" levels of the contaminants under consideration.

A considerable amount of experimental work has been carried out on the effects of contaminants on reproduction of American Kestrels (*Falco sparverius*). In order to minimize inter-species comparisons, those data are used wherever possible. Additional studies have been carried out using Barn Owls (*Tyto alba*) and Screech Owls (*Asio otus*). Toxicological studies using raptors have been summarized recently (Peakall 1987a).

The environmental levels of organochlorines associated with reproductive failure in the peregrine and other raptors, especially the Eurasian Sparrow-hawk (*Accipiter nisus*), have been widely studied (Newton 1979, 1987; Peakall 1976; Ratcliffe 1970, 1980). However, those studies dealt with correlations rather than experimental cause-and-effect relationships.

DDT/DDE/DDD

The levels in the brains of kestrels that died while on chronic DDE dosage were 200 mg/kg (Porter and Wiemeyer 1972). Stickel et al. (1984a), examined brain levels of several species of passerines that died on DDE dosage and concluded that 300–400 mg/kg was the lethal range. The figures for DDT and DDD are 100 mg/kg (Stickel and Stickel 1969) and 65 mg/kg (Stickel et al. 1970), respectively.

Significant eggshell thinning and impaired reproduction have been induced experimentally with DDE and DDT in the American Kestrel (Wiemeyer and Porter 1970; Lincer 1975; Bird et al. 1983). Hickey and Anderson (1968) considered a number of different species including raptors and concluded that eggshell thinning above 18% was associated with population decreases. A recent analysis of the data available from many parts of the world on the peregrine (Peakall and Kiff 1988) confirmed this finding. Peakall et al. (1975) considered that DDE concentrations in eggs from 15 to 20 mg/kg wet weight were associated with 20% eggshell thinning. These findings are in agreement with a detailed analysis of the relationship between DDE, productivity and shell thickness for various of species of *Falco* (Fyfe et al. 1988). They concluded that a number of species, including the Prairie Falcon (*F. mexicanus*) and Merlin (*F. columbarius*) were more sensitive than the peregrine.

The dietary level in prey needed to produce critical eggshell thinning and decreased production in the peregrine has been calculated to be 1 mg/kg (Enderson et al. 1982). However, a more recent review (De Weese et al. 1986) has produced a higher figure, viz. 3 mg/kg. The actual incidence of egg breakage is hard to determine under field conditions. Parental behaviour may also have a role (Ratcliffe 1970), but Nelson (1976) considered that there was little evidence to implicate aberrant behaviour as a cause of egg breakage in the peregrine.

The best estimate of critical levels of DDE are as follows:

Mortality: Brain levels above 200 mg/kg.
Eggshell thinning: Levels in eggs 15–20 mg/kg.
Dietary levels: above 1 mg/kg.

Dieldrin

Mortality caused by dieldrin is associated with brain levels above 4–5 mg/kg (Heinz and Johnson

1982). Reichel et al. (1974) found a peregrine with over 5 mg/kg in the brain and attributed the death to dieldrin poisoning. Dieldrin has been recognized as a causative factor in the deaths of raptors in the United Kingdom (Ratcliffe 1970; Newton 1979).

No studies have been carried out on the effects of dieldrin alone on reproduction in kestrels, but analysis of the studies with DDE + dieldrin and DDT + dieldrin (Wiemeyer et al. 1986) suggest that the critical level is about 4 mg/kg. Dieldrin at 0.5 mg/kg in the diet of Barn Owls resulted in egg levels of 8 mg/kg but did not cause adverse effects on reproduction (Mendenhall et al. 1983). Lockie et al. (1969) associated egg levels above 1 mg/kg with decreased productivity in the Golden Eagle (*Aquila chrysaetos*). The studies of Henny et al. (1983) on the American Kestrel shows that at least some hatching occurs when levels of dieldrin are in the range of 2r4 ppm.

The best estimate of critical levels of dieldrin are:

Mortality: Brain levels above 4 mg/kg.

Reproductive effects: The value of 1 mg/kg in the egg is used although it recognized that the value may be as high as 4 mg/kg.

Polychlorinated biphenyls (PCBs)

Interpretation and study of PCB effects is complicated by the large number (up to 209) of chemically distinct isomers and the varying toxicity and persistence of individual PCB congeners. Only recently has it been possible to analyse routinely for all of the congeners which may be present in an environmental sample (Mullin, et al. 1984). All studies on raptorial birds have been with commercial mixtures of PCBs.

Stickel et al. (1984b), using data from four passerine species, considered that brain levels of Aroclor 1254 above 310 mg/kg increased the likelihood of mortality. In experiments on Kestrels, a dosage of 5 mg/kg Aroclor 1254 resulted in egg levels of 40 mg/kg (Lincer 1972) and in Screech Owls, a dosage of 3 mg/kg resulted in 7 mg/kg in eggs (McLane and Hughes 1980). In neither experiment were adverse reproductive effects observed. Both of these studies showed no effect of PCBs on eggshell thickness, a finding confirmed in other species (Peakall 1987b).

Newton and Bogan (1978) initially correlated PCB levels in eggs of Sparrow-hawks with egg failure; however, more recent analysis of their data (Newton et al. 1986) did not confirm this finding.

The best estimate of critical levels of "total PCBs" are:

Mortality: Brain levels above 300 mg/kg.

Reproductive effects: Egg levels greater than 40 mg/kg.

Other organochlorines

Henny et al. (1983) found levels of heptachlor epoxide (HE) greater than 1.5 mg/kg in eggs associated with lower reproductive success of American Kestrels. Stickel et al. (1979) found brain levels of 9–27 mg/kg HE associated with mortality in passerine species fed heptachlor, but levels of 3–8 mg/kg HE in brains of birds that died after feeding with chrlordane. Blus et al. (1983) attributed the deaths of two Red-shouldered Hawks (*Buteo lineatus*) and a Great Horned Owl (*Bubo virginianus*) to high levels of HE and oxychlordane.

We were unable to find published studies on the experimental effects of oxychlordane, chlordane or nonachlor on avian reproduction. Oxychlordane levels of 6–16 mg/kg in the brain were associated with mortality of passerines fed chlordane (Stickel et al. 1979). Blus et al. 1983 found levels of 3–8 mg/kg of heptachlor expoxide and 1–5 mg/kg of oxychlordane in the brains of experimental birds dying from chlordane poisoning.

Few studies have examined the effects of hexachlorobenzene (HCB) on avian reproduction. Boersma et al. (1986) found that HCB levels greater than 4.3 mg/kg wet weight, in Herring gull (*Larus argentatus*) eggs caused mortality of 50% of the embryos. Egg levels of 6 mg/kg HCB reduced chick survival in Quail (*Coturnix coturnix*) (Schwetz et al. 1974).

The best estimates of critical levels are:

Mortality: Heptachlor expoxide, brain levels above 4 mg/kg.

Oxychlordane, brain levels above 6 mg/kg.

Reproductive effects: Heptachlor epoxide, egg levels above 1.5 mg/kg.

Hexachlorobenzene, egg levels above 4 mg/kg.

Mercury

The avian toxicology of mercury was reviewed recently (Scheuhammer 1987). Toxicity depends on whether the mercury is in the organic or inorganic form, as only a small percentage of inorganic mercury is absorbed by the intestine, whereas organic mercury is absorbed completely (Berglund and Berlin 1969). However, the residue data available to us report only total mercury.

Koeman et al. (1971) in studies feeding methylmercury (MeHg) to European Kestrels (*Falco tinnunculus*) found that brain levels of 25–33 mg/kg and liver levels of 50–120 mg/kg were associated with mortality. In experiments with Red-tailed Hawks (*Buteo jamaicensis*), Fimreite and Karstad (1971) found liver levels of about 20 mg/kg in birds killed by MeHg. Fimereite (1971) found that a diet containing 2–3 mg/kg MeHg caused decreased hatchability of eggs of Ring-

TABLE 2. Summary of the residue levels of organochlorines and mercury in the eggs of Canadian Peregrine Falcons. Residue levels in mg/kg, wet weight.

	n		DDE	tDDT	PCBs	Diel	HE	HCB	OxyC	Hg
					Falco peregrinus pealei					
1965-1972	12	Mean	7.84	8.13	n.d.	0.062	0.015	0.045	0.011	0.869
		Min	0.57	0.75	n.d.	0.010	0.000	0.000	0.000	0.000
		Max	29.30	30.51	n.d.	0.164	0.049	0.230	0.149	5.000
1980-1986	4	Mean	5.84	5.87	8.54	0.027	0.040	0.142	0.148	n.d.
		Min	5.26	5.27	7.97	0.023	0.037	0.074	0.131	n.d.
		Max	6.57	6.62	9.80	0.036	0.043	0.190	0.174	n.d.
					Falco peregrinus anatum					
1965-1972	12	Mean	32.75	33.45	n.d.	0.901	0.212	0.027	n.d.	0.347
		Min	12.60	13.32	n.d.	0.230	0.087	0.001	n.d.	0.130
		Max	194.80	199.29	n.d.	8.000	0.560	0.132	n.d.	0.560
1973-1979	34	Mean	11.20	11.83	5.83[1]	0.518	0.240	0.049	0.088[2]	0.300[3]
		Min	1.86	1.87	2.34	0.120	0.030	0.000	0.000	0.060
		Max	28.90	33.57	16.31	3.510	1.608	0.315	0.019	0.719
1980-1987	74	Mean	9.13	9.23	3.97	0.287	0.236	0.279	0.117	0.446[4]
		Min	1.51	1.52	1.58	0.050	0.000	0.000	0.000	0.120
		Max	44.10	46.53	30.70	2.450	2.710	1.060	0.840	1.140
					Falco peregrinus tundrius					
1965-1972	27	Mean	9.90	10.97	n.d.	0.794	0.258[5]	n.d.	n.d.	0.597[6]
		Min	2.66	3.78	n.d.	0.254	0.018	n.d.	n.d.	0.230
		Max	72.03	73.37	n.d.	2.450	0.656	n.d.	n.d.	3.050
1973-1979	13	Mean	8.55	8.96	11.56[7]	0.491	0.207	0.048	0.019[8]	0.138
		Min	2.81	3.15	3.07	0.140	0.080	0.010	0.009	0.019
		Max	19.60	20.00	37.54	1.860	1.749	0.133	0.090	0.710
1980-1986	26	Mean	6.84	7.27	9.82	0.574	0.390	0.045	0.160	0.092
		Min	1.61	1.78	1.61	0.090	0.060	0.016	0.000	0.000
		Max	18.50	19.08	32.25	2.890	2.070	0.350	0.309	0.420

n = sample size; means are geometric; (1) n = 25; (2) n = 25; (3) n = 20; (4) n = 20; (5) n = 13; (6) n = 16; (7) n = 10; (8) n = 7; n.d. = not determined.

necked Pheasants (*Phasianus colchicus*). Unhatched eggs contained 0.5–1.5 mg/kg mercury. Barr (1986) found that impaired reproduction of Common Loons (*Gavia immer*) was associated with 0.3 to 0.4 mg/kg MeHg in diet and somewhat over 1 mg/kg in eggs.

The best estimates of critical levels of total mercury are:

Mortality: Brain levels > 15 ppm. Liver levels > 20 ppm.

Reproductive effects: Egg levels > 1 ppm.

The criteria listed above apply to single chemicals. Under real world conditions exposure to mixtures is the norm; furthermore, the levels of contaminants are usually strongly cross-correlated (Enderson et al., 1982; Court et al. 1990). Although our knowledge of wildlife toxicology is not adequate for us to tackle the problem mathematically, it is most likely that the effects should be considered as additive (Vouk et al. 1987).

Levels of Environmental Contaminants and Their Relationship to Peregrine Population Changes

Most samples were collected when and where they became available rather than in a systematic fashion. Such an approach, although advantageous from a conservation viewpoint, has drawbacks from a scientific viewpoint. The first difficulty is whether the use of addled eggs biases the data towards higher levels since it can be argued that those eggs with the highest residues are those least likely to hatch. However, analysis of fresh and addled eggs collected in Alberta between 1985 and 1987 showed no significant differences for any of the major residues. Ambrose et al. (1988a) in their studies in Alaska also found no significant difference between randomly collected and addled eggs. Secondly, it is necessary to group the data in order to obtain a large enough sample size. Temporal trends are considered in three broad categories, "organochlorine pesticide era in North America (1965-1972)"; "immediate post restriction (1973 to 1979)" and the "current period (1980-1986)". During the second period chlordane was still used extensively. The last period is the time following restrictions on chlordane, and represents the current situation.

Detailed tabulation of the chemical analyses for OCs and mercury content of eggs and tissues are given elsewhere (Noble and Elliott 1988). The values for the principal OC residues — DDE,

TABLE 3. Temporal trends in organochlorine levels in Peregrine Falcon eggs in northern Alberta.

Year	Sample size	Residue mg/kg (wet wt, geometric mean & range) DDE	Dieldrin	PCBs
1972	4	41.9 (12.6 - 78.5)	1.67 (0.61 - 2.48)	-
1974	5	9.89 (1.86 - 18.4)	0.51 (0.14 - 1.04)	5.76 (2.34 - 8.58)
1977	3	11.08 (7.30 - 16.9)	0.50 (0.20 - 0.87)	7.10 (3.27 - 11.10)
1978	5	10.38 (5.72 - 16.50)	0.42 (0.23 - 1.07)	5.26 (3.02 - 9.86)
1979	2	8.12 (8.01 - 8.24)	0.32 (0.21 - 0.51)	3.95 (3.80 - 4.10)
1980	3	14.14 (10.70 - 16.50)	0.74 (0.54 - 1.13)	5.31 (3.47 - 10.50)
1981	6	8.84 (2.07 - 29.20)	0.36 (0.15 - 1.52)	4.64 (2.61 - 11.70)
1983	4	6.91 (2.78 - 16.6)	0.24 (0.18 - 0.35)	3.40 (1.81 - 5.83)
1985	5	10.52 (3.15 - 19.8)	0.15 (0.07 - 0.19)	3.71 (2.00 - 6.94)
1986	6	20.5 (4.6 - 44.1)	0.18 (0.01 - 0.40)	6.02 (2.53 - 10.7)
1987	7	6.21 (1.87 - 14.8)	0.01 (0.0 - 0.04)	4.28 (1.58 - 9.72)

PCBs, dieldrin, heptachlor epoxide, oxychlordane and HCB — in eggs are summarized in Table 2. It should be emphasized that, with the exception of the material from Alberta, eggs were collected as available rather than in a structured monitoring program. Nevertheless, some significant trends are seen. A distinct decrease of DDE residue levels is seen in all subspecies, whether one looks at mean or maximum values recorded. However, it is noteworthy that in *F. p. anatum* there was no decrease between the second and third periods. The levels of dieldrin in *F. p. pealei* are much lower than those found in other subspecies. Heptachlor epoxide, oxychlordane and HCB levels appear to be increasing; however, the levels are much lower in the west. No distinct trends can be seen in the data for PCBs. Analytical data are not available for this group of compounds for the first time period.

The most detailed information on residue levels in peregrine eggs is available from Alberta. This is given in Table 3. The levels of DDE were markedly higher in 1972 than in any subsequent year, which confirms the findings from other areas, but from 1974 onwards have shown no distinct trends. There is a "blip" in the 1986 data caused by two eggs from the same clutch with high residues (38 and 44 mg/kg). Dieldrin has decreased over the period and is now present in only trace amounts. PCBs, in contrast, show no distinct trends at all over the period 1974 to 1987.

The data on population trends and reproductive performance are based in the main on the four major surveys that were carried out in North America in 1970 (Cade and Fyfe 1970), 1975 (Fyfe et al. 1976), 1980 (White et al. 1990) and 1985-1986 (Murphy 1990). The limitations of extensive surveys include the difficulty of uniformity of coverage of such a wide area and with many different observers and the marked year-to-year variation in the population of peregrines (Court et al. 1988).

The relationship between the percentage of eggs containing contaminant concentrations greater than the estimated critical values, and the status of the peregrine population is summarized in Table 4. Two caveats should be made: first, any attempt to state a population trend in a single word is an oversimplification and, second, the sample sizes of eggs are often small and may be biased in favour of eggs that had high residues and thus failed. In almost all cases where the percentage of eggs with critical DDE levels approached 50% or greater the population was declining, and occupancy rates were low.

F. p. pealei, the populations of which declined considerably from the 1950s to mid 1970s, is now considered stable. Between 1965 and 1972, 42% of the eggs had residues within the critical range, whereas the small sample collected in 1986 had none. The tissue levels of nestlings from Langara Island in 1969 and 1971 were low and should not have affected survival.

F. p. anatum in the four regions listed showed signs of population recovery in the most recent

TABLE 4. Summary of occurrence of "critical" residue levels in Peregrine eggs and their relationship to population trends.

Location and time period		Contamination (Number of samples critical level/total)	Population trend
		Falco peregrinus pealei	
Langara Island	1965-1972	DDE 5/10 Hg 2/10	Decreasing
British Columbia	1986	None	Stable or increasing
		Falco peregrinus anatum	
Eastern Canada	1970	DDE 1/1	Extirpated
	1984-1987	DDE 1/6 Dieldrin 1/6	Reintroduced
Alberta	1968-1972	DDE 4/5 Dieldrin 3/5	Decreasing
	1973-1979	DDE 4/19 Dieldrin 2/19	Increasing
	1980-1987	DDE 7/56 Dieldrin 2/56	Stable
Yukon	1968-1972	DDE 5/6 Dieldrin 1/6	Decreasing
	1973-1979	DDE 3/4 Dieldrin 2/4	Decreasing
	1980-1981	DDE 5/8 Dieldrin 1/8	Stable
Mackenzie River Northwest Territories	1973-1979	DDE 3/11 Dieldrin 2/11 HE 1/11	Decreasing
		Falco peregrinus tundrius	
Ungava, Quebec	1968-1972	DDE 2/11 Dieldrin 4/11 Hg 2/11	Stable
	1973-1979	DDE 2/4 Dieldrin 3/4	Decreasing
	1980-1986	Dieldrin 2/10	Recovering
Northwest Territories	1968-1972	DDE 5/16 Dieldrin 7/16	Decreasing
	1973-1979	DDE 2/9 HE 2/9	Stable
	1980-1986	DDE 2/16 Dieldrin 4/16 HE 3/16	Increasing

*based largely on surveys carried out in 1970 (Cade and Fyfe 1970), 1975 (Fyfe et al 1976), 1980 (White et al. 1990) and 1985-1986 (Murphy 1990).

time period, corresponding to declines in the percentage of eggs containing critical levels of contaminants. A significant proportion of each population is still contaminated, but the sample sizes are small and, as the eggs obtained are those that fail to hatch, they may be biased towards high values. The levels of DDE found in the eggs of *F. p. anatum* in Canada over the period 1980-1987 (geometric mean of 9.1 mg/kg, Table 2) is very similar to the value of 10.6 reported by Ambrose et al. (1988a) for Alaskan specimens over the period 1979-1984; although their value for PCBs (2.65 mg/kg) was appreciably lower than our value of 4.54.

A clutch of five infertile eggs from the Gatineau, Quebec, in 1989 had 8–11 mg/kg DDE, 11.5–14.9 mg/kg PCBs and 0.29-0.37 mg/kg mirex. The degree of eggshell thinning was 13–14%. The levels of DDE and degree of eggshell thinning are uncomfortably close to "critical" levels. These values have not been included in the tables.

Analysis of the tissues of three peregrines found dead in the east (1, 1983: 2, 1986) showed levels below the "critical" values. Nevertheless, the three-year-old female shot in eastern Ontario in 1983 had accumulated 110 mg/kg PCBs, 30 mg/kg DDE, and 2.45 mg/kg dieldrin in her fat. This agrees with the findings of Court *et al.* (1990) showing that two- and three-year-old birds in the Arctic were as contaminated as birds six to seven years old.

DDE concentrations in three eggs from Montreal (1984, 1985) were 3, 11, and 36 mg/kg. The egg with the highest level of DDE also contained 2.2 mg/kg dieldrin and 1.1 mg/kg oxychlordane, both values in excess of "critical" levels. A pool of four eggs from an abandoned nest in Montreal in 1986 contained 10 mg/kg DDE, 12 mg/kg PCBs and two analyses (one a pool of nine eggs and one individual egg) from Quebec City had 3–4 mg/kg DDE, 7–9 mg/kg PCBs and low levels of other OCs.

F. p. tundrius populations were all apparently stable by the 1980s, and this correlates with decreases in levels of contamination. The levels found in this subspecies in a sample of 26 eggs collected over a wide geographical range over the period 1980-1986 are similar to the sample of 22 eggs from Rankin Inlet collected over the period 1982-1985 (Court et al. 1990). The values found by Ambrose et al. (1988) for Alaskan eggs over the

period 1979-1984 had somewhat higher levels of DDE (10.1 mg/kg) and substantially lower PCBs (2.04 mg/kg) than the eggs in our sample. In *F. p. tundrius* the highest levels of contamination in the eggs and lowest occupancy rates occurred in the 1970s. Nevertheless, the most likely candidate for direct poisoning was an adult male found dead at Rankin Inlet in 1982 with brain levels of 2 mg/kg dieldrin, 14 mg/kg DDE, 1.1 mg/kg oxychlordane and 60 mg/kg PCB.

Along the north slope of the Yukon, *F. p. tundrius* has been almost extirpated. By 1981 none were known to be breeding in this area and no territories have been reported since. The northern Alaskan population declined in the early 1970s but has since started to recover (Ambrose et al. 1988b).

The Ungava Bay population was healthy in 1970, but decreases were noted in the 1975 and 1980 surveys. Bird and Weaver (1988) and the 1985 survey (Murphy 1990) reported that this population is now recovering. Nevertheless, the levels in three eggs collected in 1986 had significant residues, 7–11 mg/kg DDE, 14–21 mg/kg PCBs and 0.8–2.6 mg/kg dieldrin.

Spatial Trends

In the period 1965 to 1972 DDE was significantly lower in *F. p. tundrius* populations in the central arctic and HE and dieldrin were significantly lower in *F. p. pealei* than in other populations. No data on PCBs and oxychlordane are available for this period.

In the period 1973 to 1979, only oxychlordane showed spatial differences. Levels of oxychlordane were significantly higher in eggs of *F. p. anatum* from Alberta and the Mackenzie River valley than in *F. p. tundrius* eggs from the central Arctic. Since chlordane use was relatively high in North America at this time, this suggests that *F. p. anatum* in the west spent more time out of the breeding season in North America than *F. p. tundrius* or that *F. p. anatum* use prey species that are more heavily contaminated with chlordane.

In the current period DDE, dieldrin, oxychlordane and HCH levels differed between subpopulations. The highest levels of DDE were recorded from Alberta, those of dieldrin from Ungava, those of oxychlordane in southern Quebec, and the lowest levels in the Yukon, but at a lower level of significance. It is possible that the southern Quebec peregrines acquire oxychlordane and PCBs via the Great Lakes-St. Lawrence River system. The levels of HCH in the 1986 eggs from the Queen Charlottes were an order of magnitude higher than those recorded elsewhere in Canada. Levels of this compound in the eggs of seabirds, in particular those of the Ancient Murrelet collected in 1986, were also much higher than levels in the eggs of seabirds collected from other locations in Canada (Elliott et al. 1989).

The levels of organochlorines in the prey of the peregrine in Canada are considered in Baril et al. (1990) and those from Latin America in the contribution of Fyfe et al (1990).

Conclusion

It is considered that the decline of the Peregrine Falcon in Canada was largely the result of the usage of organochlorine pesticides, especially DDT and, to a lesser extent, dieldrin. Some improvements in both natural and manipulated populations have been observed in the last two major surveys (1980, 1985-1986). The rather fragmented residue data available indicate decreases, but many OCs are still uncomfortably close to "critical" levels. Only in Alberta is a good series of temporal data available.

Our knowledge of the residue levels in the reintroduced peregrine population in eastern Canada is too limited for a definitive evaluation. The data available indicates that most residues are slightly below "critical" values. The same conclusion was reached from the well studied Rankin Inlet population (Court et al. 1990).

The situation is similar in the eastern United States. Gilroy and Barclay (1988) found mean residue levels of 3–18 mg/kg DDE and eggshell thinning averaging 12.1% for the period 1981 to 1984. They concluded that OC contaminants pose a potential threat to the re-established eastern peregrines and warrant close monitoring as restoration continues.

Data on the toxicant levels are important for management decisions on re-introduction and possible manipulation of both natural and reintroduced Peregrine Falcon populations since they can influence which sites are to be used and whether artificial incubation and hacking techniques should be used.

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A Toxicological Assessment of Peregrine Falcons, *Falco peregrinus tundrius*, Breeding in the Keewatin District of the Northwest Territories, Canada

G. S. COURT[1,6] C. C. GATES,[2] D. A. BOAG,[1] J. D. MACNEIL,[3] D. M. BRADLEY,[4] A. C. FESSER,[3] J. R. PATTERSON,[3] G. B. STENHOUSE,[5] and L. W. OLIPHANT[4]

[1]Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9
[2]Renewable Resources, Government of the Northwest Territories, Fort Smith, Northwest Territories, X0E 0P0
[3]Health of Animals Laboratory, Food Production and Inspection Branch, Agriculture Canada, 116 Veterinary Road, Saskatoon, Saskatchewan S7N 2R3
[4]Department of Veterinary Anatomy, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0
[5]Ducks Unlimited Canada, Box 2641, Yellowknife, Northwest Territories X1A 2P9
[6]Present Address: Department of Zoology, University of Otago, Dunedin, New Zealand.

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Eggshell thinning, and organochlorine residues in egg contents, blood plasma of adults and young, and prey species, were determined for Peregrine Falcons (*Falco peregrinus tundrius*) nesting at Rankin Inlet, Northwest Territories, Canada. Shells from 78 eggs representing 62 clutches of 26 pairs from 1981-1986 averaged 16% thinner than eggs collected prior to the introduction of DDT, only 1% less than the thinning level considered critical for successful reproduction in this species. About 10% of all peregrine pairs to initiate a breeding attempt failed with egg breakages. Geometric mean levels of DDE residues in addled eggs from 36 nesting attempts and in 88 blood plasma samples from adults, were 7.6 ppm (wet weight) and 0.8 ppm (wet weight) respectively. Levels of DDE in blood plasma were positively correlated with DDE levels in the contents of eggs. DDE levels in the contents of eggs were negatively correlated with shell thickness. Residues of a number of other organochlorine pesticides and polychlorinated biphenyls were found in egg contents and in the plasma of adult birds. Only DDE was found in measurable quantities in the blood plasma of nestlings. Levels of organochlorines were often highly correlated in both plasma and egg samples, suggesting that peregrines are exposed to these compounds collectively. All but one of 11 prey species sampled showed measurable levels of organochlorines. Only one species, an insectivorous passerine, contained DDE residues high enough to potentially affect breeding success of peregrines in the study area, while one duck and two shorebird species were the only other prey species to show elevated DDE levels. Relatively low pesticide residues and high reproductive success of this population, however, are explainable through the low proportion of highly contaminated migratory prey species used by these birds on the breeding grounds. Additionally, asynchrony in the arrival times of peregrines and contaminated migratory prey species results in the use of relatively uncontaminated prey before laying. Recommendations are presented for future monitoring of pollution and population trends of tundra peregrines in Canada.

L'amincissement de la coquille, le contenu en résidus organochloriques de l'oeuf ainsi que du plasma sanguin des adultes, des jeunes et des proies ont été déterminé chez des faucons pèlerin (*Falco peregrinus tundrius*) nichant à Rankin Inlet, Territoires du Nord-Ouest, Canada. Les coquilles de 78 oeufs, représentant 62 couvées produites par 26 couples, de 1981 à 1986, étaient en moyenne 16% plus mince que celles recueillies avant 1947, soit seulement 1% de moins que la valeur critique assurant le succès de la reproduction. Environ 10% des couples qui ont tentés de se reproduire ont échoué suite à la rupture de la coquille des oeufs. La concentration moyenne de residus en DDE chez des oeufs stériles provenant de 36 tentatives de nidification et de 88 échantillons de plasma sanguin d'adultes était respectivement de 7.6 et de 0.8 ppm (poids frais). Il existe une corrélation positive entre la concentration en DDE du plasma sanguin et celle des oeufs. La concentration en DDE du contenus des oeufs est négativement corrélée avec l'épaisseur de la coquille. D'autre pesticides organochloriques et biphényles polychlorés ont également été trouvé dans le contenu des oeufs et le plasma sanguin d'oiseaux adultes. Cependant, seulement le DDE a été trouvé en quantité mesurable dans le plasma sanguin des oisillons. Les concentrations des différents produits organochloriques sont fortement corrélées entre elles dans les échantillons de plasma sanguin et d'oeufs, suggérant que les faucons pèlerin sont exposé à ces produits collectivement. Sur un total de 11 espèces de proies analysés, 10 ont démontré des concentrations détectables en produits organochloriques. Une espèce de passereau contenaient des concentrations suffissament élevées pour affecter le succès reproducteur des faucons pèlerin. La concentration relativement faible des pesticides et le succès reproducteur élevé de cette population peut être attribuable à la faible proportion de proies fortement contaminé utilisé par ces oiseaux dans les aires de nidification. De plus, l'asynchronie entre l'arrivé des faucons et les proies fortement contaminé résulte en l'utilisation de proies faiblement contaminées avant la ponte. Des recommendations ayant traits au suivi de la pollution et des population faucons pèlerin de la toundra Canadienne sont présentées.

Key words: Peregrine Falcons, *Falco peregrinis tundrius*, organochlorines, DDT, DDE, Keewatin District, Northwest Territories.

The association between pesticide contamination and reproductive failure in the Peregrine Falcon (*Falco peregrinus*) has been the focus of much of the research on this species over the last three decades (Ratcliffe 1967; Enderson and Berger 1968; Hickey 1969; Lincer et al. 1970; Ratcliffe 1970; Cade and Fyfe 1970; Cade et al. 1971; Peakall et al. 1975; Fyfe et al. 1976; Enderson et al. 1982). The widespread decline of the peregrine in North America has been attributed to reproductive failures following the indiscriminate use of certain chlorinated hydrocarbon pesticides, most notably DDT (summaries in Peakall 1976; Cade et al. 1988). DDT was banned from use in Canada in 1969 and the United states in 1972 (Kiff 1988), but by 1975 the peregrine of continental North America, *F. p. anatum*, had been extirpated over its range east of the Rocky Mountains and south of the boreal forest (Fyfe et al. 1976).

In addition to documenting the decline of the subspecies *anatum*, three North American Peregrine Falcon Surveys (Cade and Fyfe 1970; Fyfe et al. 1976; White et al., this issue) identified localized declines in populations of *F. p. tundrius*, the peregrine nesting above the treeline on the northern mainland, and on the arctic coast and islands. There exists evidence of pesticide contamination in the tundra subspecies (Cade et al. 1971; Peakall et al. 1975; Ambrose et al. 1988; Peakall et al., this volume), and there are reports of populations showing a decrease in the numbers of breeding pairs as well as reduced production of young (Cade and Fyfe 1970; Peakall et al. 1975; Fyfe et al. 1976; White et al., this issue). It has been established that much of the contamination in arctic populations originates in Central and South America, where northern peregrines and many of their primary prey species spend the winter months (Henny et al. 1982). Many countries in Latin America continue to use persistent organochlorine pesticides now banned from use in Canada and the United States (Peakall 1976; Burton and Philogène 1988). Curiously, among reports of reduced reproductive success and population declines, there are other studies of the peregrine in the Nearctic reporting dense and productive populations (Alliston and Patterson 1978; Calef and Heard 1979; Kuyt 1980; Burnham and Mattox 1984; Court et al. 1988a). Nevertheless, there exists concern as to whether continued exposure to foreign sources of pollution is causing reproductive failure in populations of *tundrius*, and whether population declines, similar to those observed in southern Canada in the 1960's and 1970's, are imminent. Presently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists this subspecies as 'threatened'.

One of the difficulties in interpreting the results of recent population surveys of the tundra Peregrine Falcon, and of assessing the threat posed by remote sources of pollution, is that there has been no detailed toxicological assessment of a tundra population of peregrines in Canada. The majority of studies to date consist of periodic surveys of population size and breeding success (Cade and Fyfe 1970; Fyfe et al. 1976; Alliston and Patterson 1978; Calef and Heard 1979; Kuyt 1980), whereas pesticide monitoring has consisted mainly of measuring pollutants in addled eggs collected incidentally during population surveys (Berger et al. 1970; Peakall et al., this volume). Between 1981 and 1986 we had the opportunity to conduct a detailed study of tundra Peregrine Falcons nesting along the northwest coast of Hudson Bay. We studied the breeding biology and ecology of this population (Court 1986; Court et al. 1988a), monitored population trends and productivity (Court et al. 1988b), measured turnover and mortality rates of adults (Court et al. 1989), and documented migration and wintering behavior through band returns (Court et al. 1988a). In addition to this work, a large portion of the effort each field season was devoted to the collection of samples to be used in an investigation of pesticide pollutant accumulation. Here, we summarize our findings on eggshell thinning, organochlorine residues in eggs and blood plasma, the relationships between pesticide levels and both breeding success and adult mortality, and pollutant levels in primary prey species. We discuss the implications of these findings regarding the "health" of the arctic subspecies in terms of pollutant levels, and suggest how arctic populations of the peregrine in Canada are best monitored in the future.

Study Population

Research was conducted on a study area near the community of Rankin Inlet, Northwest Territories (N.W.T.), Canada, on the western coast of Hudson Bay (62°49'N, 92°05'W) from May to September, 1981 to 1986. Terminology used in describing nesting activities of peregrines and a general description of vegetation, climate, and geology of the study area are reported elsewhere (Court 1986, Court et al. 1988a, 1988b, 1989). At its peak, the density of breeding peregrines at Rankin Inlet included 26 territorial pairs at one pair per 17 km^2, a density that is among the highest for the species in the world and the highest recorded in the tundra biome. Productivity was as high as any population in the world, reflecting an abundant prey base comprised of 19 species of birds and three mammals (Court et al. 1988a). The size and productivity of the peregrine population varied with the availability of prey and spring weather conditions. This breeding population increased by 30% and productivity nearly doubled in a year of

peak microtine abundance, whereas productivity was reduced to less than one-half of the yearly average in a year of poor spring weather (Court et al.1988b).

Methods

Between 1981 and 1985, eggshell fragments were gathered from both unsuccessful and successful nests in the Rankin Inlet population. In 1986, a spring storm severely reduced hatching success in the population (Court et al. 1988b) providing a sample of whole shells from 27 "storm-killed" eggs representing 14 clutches. Eggshells were measured optically using a Leitz Wetzlar UWM Toolmaker's Microscope Micrometer, accurate to $\pm$ 0.0025 mm. With fragment samples, mean eggshell thickness was determined from three chips selected at random from the collection at each nest. For whole eggs, measurements were from fresh chips taken at three places on the equator of the shell. Most measurements included the shell and shell membrane. In 41 instances where shell membranes were absent, the average membrane thickness of 0.069 mm for 47 eggs was added to the shell thickness. Where more than one egg from a clutch was available (n = 23), we calculated mean clutch thickness and included the measurement as a single egg representing a clutch.

Between 1982 and 1985, addled peregrine eggs were collected from both successful and unsuccessful nests in the study population. At successful nests, addled eggs were collected within seven days of the hatch of the youngest nestling. In 1986, most of the "storm-killed" eggs were left in peregrine nests until it was clear that they had been abandoned. Consequently, all but two eggs in this sample showed some degree of addling, with embryo development having been stopped during the first week of incubation. Egg contents were stored in acetone-rinsed vials, sealed with a foil-lined stopper, and frozen. Egg samples were analyzed for percentage of water, percentage of lipid, and residues of selected organochlorine pesticides and polychlorinated biphenyls (PCBs). Methodology followed the Canadian Wildlife Service Analytical Manual (Won 1982). For dry weight determination, the egg material was mixed and a 2 g sub-sample was dried to constant weight at 105°C. For analysis, a second 2 g sample was weighed into a mortar containing 20 g sodium sulfate, ground to a free flowing powder, and transferred to a column containing 20 cm sodium sulphate. The mortar and pestle were rinsed with hexane, which was added to the column. Sufficient hexane was added to the column to just wet contents. After standing for 30 minutes, the column was eluted with 300 mL dichloromethane-hexane (1:1). The eluate was collected and the volume was reduced to 8 mL using a rotary evaporator. The eluate was split into two 4 mL portions, one of which was used for lipid analysis by evaporation of the solvent at room temperature, followed by oven drying at 105°C for 10 to 20 minutes. The second aliquot was transferred to an 8 g Florisil mini-column and eluted in sequence with hexane, 15% dichloromethane in hexane, 80% dichloromethane in hexane, and finally dichloromethane, collecting 4 fractions. The Florisil was used as supplied and the elution volumes adjusted to give the required elution pattern. The first fraction was concentrated by evaporation to 10 mL, while the remaining three were concentrated to 1 mL using an N-evap. All fractions were then analyzed by gas chromatography on a 0.15 m DB-608 capillary column, 0.53 mm ID, using a Ni^{63} electron capture detector and external standard calibration method. Positive findings were confirmed using a GC-MS system equipped with a 30 m DB-5 capillary column, 0.25 mm ID, using positive or negative ion detection and electron impact or chemical ionization mode, as appropriate.

For blood plasma sampling, adult Peregrine Falcons were trapped as they arrived on the study area in the spring and at the nest over eggs or small young. Trapping techniques are not described in detail to limit possible abuses. Blood was collected from the brachial vein of each bird using a 23 gauge needle and a 3 cc syringe. In 1982, nestlings handled for banding purposes were sampled for blood; all were between 21 and 25 days of age. Whole blood samples (1.0 cc-2.5 cc) were stored in 5 cc heparinized vacutainers until centrifuged. After spinning, blood plasma was stored frozen in sterilized 5 cc vacutainers pending analysis. Blood plasma samples were analyzed for residues of selected organochlorine pesticides and PCBs using silica gel for clean up and fractionation as described by Burse et al. (1983). Individual samples (0.25 mL-1.50 mL) were weighed, added to 2 mL methanol, and mixed. Mixtures were extracted three times with 5 mL hexane-ethyl ether (1:1). Each time the extract was centrifuged at 1800 rpm for 6 minutes and the supernatant removed. The combined supernatants were concentrated to 0.5 mL using an N-evap. The concentrated extract was then added to a column containing a slurry of 5 g activated silica gels in pentane and eluted with 1% benzene in pentane, collecting three 15 mL fractions and the interface; following this, the column was washed with benzene and two 15 mL fractions were collected. The fractions were evaporated to dryness on a N-evap and then dissolved in 1 mL iso-octane. All fractions were analyzed by gas chromatography on a 2 m X 4 mm ID glass column packed with 1.5% SP-2250/1.95%

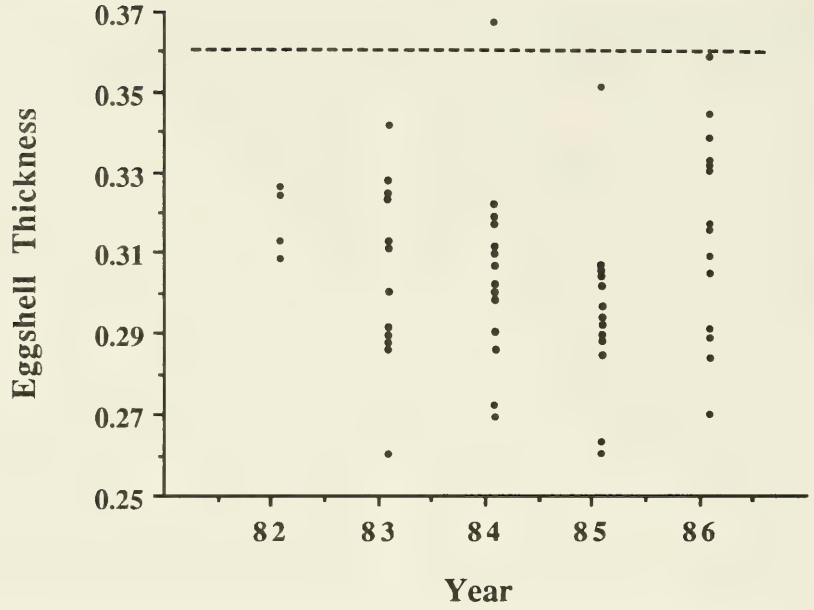

FIGURE 1. Shell thickness (mm) of Peregrine Falcon eggs representing 62 clutches from Rankin Inlet. The broken line represents a weighted average shell thickness for arctic Peregrine eggs collected before the introduction of DDT (Berger et al. 1970; Anderson and Hickey 1972; Walker et al. 1973).

SP-2401 on 100/120 Supelcoport, with detection using a Ni^{63} electron capture detector. Quantitation was by external standard against a calibration mixture of known concentrations. Gas chromatographic confirmations were done by comparison of chromatographic results on a 2 m X 4 mm ID glass column packed with 5% Dexsil 300 on Gas-Chrom Q, 80/100 mesh. GC-MS confirmations were performed as described above for the egg content samples.

Between 4 and 10 adults of each of 11 common prey species were shot on the study area in late May and early June of 1982 and 1983. All specimens were collected within 10 km of occupied Peregrine Falcon nesting sites. Fresh specimens were wrapped in foil and frozen. Samples were prepared for analysis by removing the feet, beak, feathers, and large intestine. Samples of each species were pooled by date and collection site, ground with a Hobart chopper/grinder, sub-sampled, and homogenized. Analysis then proceeded as described above for the eggs, using 5 g analytical subsamples. Selected tissues from dead adult Peregrine Falcons were homogenized and analyzed similarly.

All residues in egg contents, plasma samples, prey species, and tissues from adult peregrines are expressed as parts per million (ppm) wet weight of the samples. Residue data were skewed to the left, so for statistical comparisons individual values were transformed to a $\log_{10}$ scale. All means presented for residue data are geometric, unless stated otherwise. Eggshell thickness, egg lipid content, egg water content, and brood size data were normally distributed, so no transformation was necessary and means for these data are arithmetic $\pm$ one standard deviation (SD). Statistical tests follow Sokal and Rohlf (1981). Differences among data sets were considered significant when the probability value (P) was ≤ 0.05.

Results

Eggshell Thickness

Collections of eggshell fragments and whole shells allowed shell thickness measurements on 78 peregrine eggs from Rankin Inlet. Pre-pesticide peregrine eggs from the coastal Keewatin District were not available, so we compared eggshell thickness of eggs to a weighted mean eggshell thickness calculated from three pre-pesticide collections of peregrine eggs from the Nearctic (Berger et al 1970; Anderson and Hickey 1972; Walker et al. 1973) (Figure 1). Mean shell thickness for eggs representing 62 clutches was 15.8% thinner than the average pre-DDT shell thickness for peregrines from the Nearctic (0.303 $\pm$ 0.023 mm vs 0.360 mm). Eggshells ranged in thickness from 0.258 mm to 0.365 mm, with the thinnest shell in the sample 28% thinner than the pre-DDT mean.

TABLE 1. Eggshell thickness of Peregrine Falcons nesting at Rankin Inlet

Sample	*n*	Mean (± SD) eggshell thickness (mm)	Difference (*P*)[1]
All eggs	78	0.306 ± 0.003	
Eggs representing clutches	62	0.303 ± 0.023	
Eggs recovered as fragments	32	0.309 ± 0.023	0.062
Eggs recovered intact	30	0.298 ± 0.022	
Eggs from successful nests	40	0.302 ± 0.019	0.045
Eggs from unsuccessful nests	9	0.287 ± 0.006	
Addled eggs 1981 to 1985	14	0.293 ± 0.023	0.032
"Storm-killed" eggs 1986	16	0.313 ± 0.025	

[1]Based on Student's t-tests.

Only 12 (19%) of 62 eggs representing clutches showed less than 10% thinning. In our sample, shell thickness did not vary significantly among years (ANOVA $F_{4,57} = 1.748$ $P = 0.152$). Mean shell thickness for eggs recovered as fragments was not significantly different to that for whole eggs (Table 1). Shells from addled eggs collected between 1981 and 1985 were significantly thinner that those from the "storm killed" sample of 1986 (Table 1).

TABLE 2. Levels of organochlorine residues in Peregrine Falcon eggs from 36 different nesting attempts[1] at Rankin Inlet.

Compound	Range	Geometric Mean
DDE	1.79-29.27	7.59
PCB	1.95-47.76	8.74
Dieldrin	0.13-1.66	0.41
Heptachlor Epoxide	0.09-5.92	0.36
Oxychlordane	0.08-0.80	0.21
DDT	0.0-1.41	0.10
DDD	0.0-0.37	0.04
Hexachlorobenzene	0.0-0.15	0.03

[1]Includes residues from 25 single eggs and 11 clutch means.

Nine of 14 nesting failures in 91 nesting attempts (1981 to 1985) involved breakage of one or more eggs in a clutch (Figure 2). Shells from failed nests averaged 20.2% less than the pre-DDT average, while those from successful nests averaged 16.1% less than the pre-DDT average; the difference was significant (Table 1). We found no significant correlation between shell thickness and number of young fledged (n = 62 r = 0.64 $P = 0.677$).

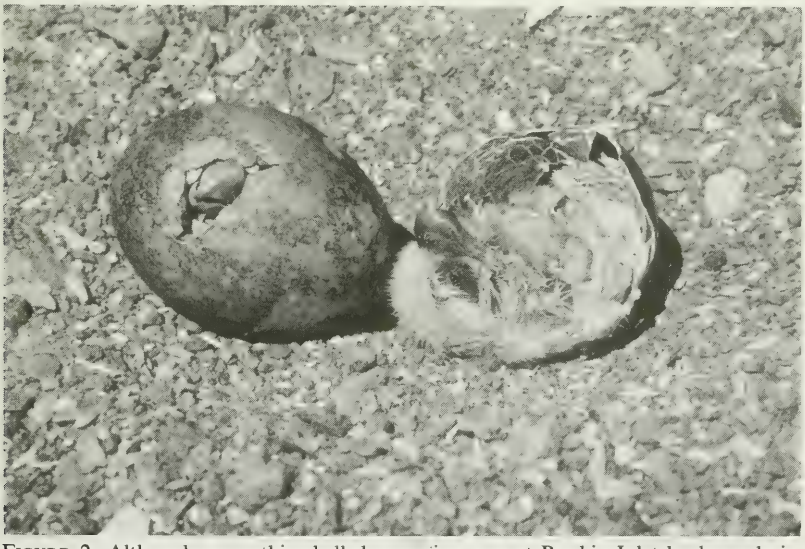

FIGURE 2. Although many thin-shelled peregrine eggs at Rankin Inlet broke early in incubation, some collapsed just as eggs pipped (egg on right). Other failures were caused by fine cracks in the shell originating from the point of 'pip', allowing increased moisture loss, causing the shell membrane to shrink around the chick, preventing hatch (egg on the left). Photo by G. S. Court.

TABLE 3. Correlation coefficients (r values) between concentrations of different organochlorine compounds and eggshell thickness in Peregrine Falcon eggs from 36 different nesting attempts at Rankin Inlet.

	DDE	PCB	Dieldrin	Heptachlor Epoxide	Eggshell Thickness
DDE	1.00				
PCB	0.786**	1.00			
Dieldrin	0.540**	0.483*	1.00		
Heptachlor Epoxide	0.567**	0.459**	0.491*	1.00	
Eggshell Thickness	0.530**	0.419*	0.127^{ns}	0.282^{ns}	1.00

ns = not significant; $*P < 0.05$; $**P < 0.01$.

Organochlorine Residues in Eggs

A total of 52 peregrine eggs, representing 36 clutches, was collected and analyzed for organochlorine residues. Two eggs were eliminated from data analyses because of excessive moisture loss, however, none of the remaining 50 eggs showed water content below 70%. Mean water content for all eggs was 78.98 ± 2.96%. The mean lipid content was 5.45 ± 2.37%. There was no significant difference in the water content of addled eggs collected at nests prior to 1986, and the "storm-killed" sample from 1986 ("pre-1986" n = 21 mean = 78.98 ± 2.97%; 'storm-killed' n = 14 mean = 79.24 ± 4.70% Student's t-test $t_{33} = -0.198$ P=0.844). Likewise, mean lipid content of eggs from the two groups did not differ significantly ('pre-1986' n = 21 mean = 5.45 ± 2.37%; 'storm-killed' n = 14 mean = 5.43 ± 3.30% Student's t-test $t_{33} = 0.086$ P=0.932). Residues of the eight most commonly detected organochlorines in egg contents are summarized in Table 2.

In most cases there was little variability in DDE residues in eggs from the same clutch; the difference between highest and lowest DDE levels in eggs of 12 clutches averaged 2.23 ppm (arithmetic mean). Of the eggs sampled between 1982 and 1985, 12 were from pairs that successfully fledged young and 11 were from pairs that failed before eggs hatched; there was no significant difference in the mean DDE residues of eggs from the two groups (pairs successful - 6.57 ppm versus pairs unsuccessful - 7.76 ppm Student t-test $t_{21} = -0.292$ $P = 0.773$). Despite the fact that the "storm-killed" eggs had shells significantly thicker than those of the addled eggs collected between 1982 and 1985, the two samples did not differ significantly in mean DDE levels in egg contents ("pre-1986" n = 20 mean = 7.44 ppm; "storm-killed" n = 15 mean 7.53 ppm Student's t-test $t_{33} = -0.059$ $P = 0.953$). We found no significant correlation between DDE and PCB residues in eggs and number of young fledged (DDE n = 18 r = 0.01 $P = 0.966$; PCB n = 18 r = 0.12 $P = 0.637$).

FIGURE 3. Demonstration of the technique used for obtaining plasma samples from an individual Peregrine Falcon. Photo by C. C. Gates.

TABLE 4. Organochlorine residues in Peregrine Falcon blood plasma samples taken at Rankin Inlet.

	Adult Males		Adult Females		Nestlings	
Compound	Range	Geometric mean (n)	Range	Geometric Mean (n)	Range	Geometric Mean (n)
DDE	0.18-8.19	0.93 (22)	0.15-6.56	0.76 (62)	0.00-0.08	0.02 (19)
PCB	0.00-2.55	0.23 (22)	0.00-3.84	0.53 (62)	ND	-
Dieldrin	0.00-0.30	0.05 (22)	0.00-0.27	0.07 (62)	ND	-
Heptachlor Epoxide	0.00-0.35	0.06 (22)	0.00-0.72	0.04 (62)	ND	-

Differences between residue means of male ;and female samples - Student's t test on log transformed values: DDE $t_{82} = 1.075$ $P = 0.285$; PCB $t_{82} = -2.006$ $P = 0.048$; Dieldrin $t_{82} = 1.373$ $P = 0.174$; and Heptachlor Epoxide $t_{82} = 0.926$ $P = 0.357$.
ND = not detected.

Correlations between concentrations of organochlorine residues in eggs are presented in Table 3. A particularly strong correlation was observed between residues of DDE and PCBs, but significant correlations were found between all of the four most common organochlorine compounds detected in the samples.

Organochlorine Residues in Blood Plasma and Carcasses

During the study, we captured and bled adult peregrines a total of 84 times (Figure 3). Some adults were sampled more than once if captured in more than one year. Three adult males and 13 adult females were sampled in late May, shortly after their arrival on the breeding grounds. Nineteen adult males and 49 adult females were captured and sampled after clutch completion. Nine females were captured and sampled during late incubation, while the remaining 40 females and all of the males were captured and sampled after the hatch, when young were between 5 and 25 days of age (July 15 to August 10). Eighteen nestlings were sampled for plasma.

Significant levels of DDE, Dieldrin, Heptachlor Epoxide, and PCBs were found in the plasma of adult peregrines (Table 4). There was no significant difference in the levels of DDE, Dieldrin, and Heptachlor Epoxide in the plasma of adult male and female peregrines, however, females carried significantly higher levels of PCBs than males (Table 4). There was no significant difference among years in the plasma levels of DDE or PCBs (DDE - ANOVA $F_{4,79} = 0.632$ $P = 0.641$; PCB - ANOVA $F_{4,79} = 0.528$ $P = 0.715$).

Only DDE was found in measurable quantities in the plasma of nestlings. No significant correlation was found between the levels of DDE in the plasma of adult females (sampled post-laying) and DDE levels in the plasma of their young (n = 8 r = 0.49 $P = 0.190$), or between levels of DDE in plasma of adult females and the number young they fledged (n = 48 r = 0.092 $P = 0.526$).

Levels of DDE in adults fluctuated from year to year with up to three fold changes in DDE levels in the same bird sampled in the same month of different years. A female captured in 1982 carried 0.66 ppm DDE in the plasma; the same bird sampled in 1985 had 1.45 ppm DDE in plasma. Another female captured in 1982 carried 0.91 ppm

TABLE 5. Correlation coefficients (r values) between concentrations of different organochlorine compounds in 84 adult Peregrine Falcon blood plasma samples taken at Rankin Inlet.

	DDE	PCB	Dieldrin	Heptachlor Epoxide
DDE	1.00			
PCB	0.530**	1.00		
Dieldrin	0.296*	0.259*	1.00	
Heptachlor Epoxide	0.289**	0.119^{ns}	0.440**	1.00

ns = not significant; $*P < 0.05$; $**P < 0.01$.

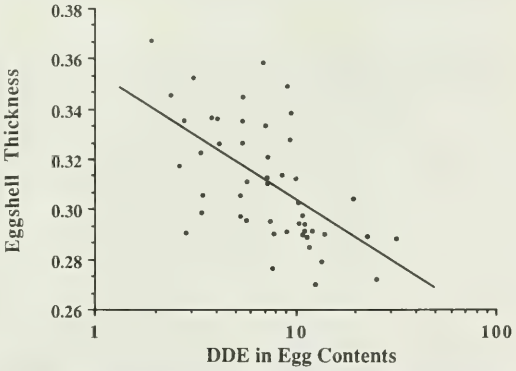

FIGURE 4. The relationship between log DDE in egg contents (ppm wet weight) and eggshell thickness (mm) for Peregrine Falcons nesting at Rankin Inlet (eggshell thickness = 0.3514-0.0526log DDE in egg contents n = 50 r = -0.60 $P < 0.001$).

TABLE 6. Geometric mean levels of organochlorine residues in the blood plasma of male and female Peregrine Falcons captured at different times in the breeding season at Rankin Inlet.

Sex/season	*n*	DDE (range)	PCB (range)	Dieldrin (range)	Heptachlor Epoxide (range)
Males sampled in spring	3	1.16 (0.19-8.19)	0.14 (0.00-2.21)	0.10 (0.00-0.23)	0.02 (0.00-0.35)
Males sampled in summer	19	0.90 (0.26-2.52)	0.23 (0.00-2.55)	0.05 (0.00-0.30)	0.07 (0.02-0.23)
Females sampled in spring	13	1.10 (0.28-6.56)	0.52 (0.01-3.84)	0.04 (0.00-0.23)	0.02 (0.00-0.23)
Differences[1] (*P*)		0.039	0.928	0.007	0.059
Females sampled in summer	49	0.68 (0.15-2.65)	0.54 (0.00-3.49)	0.08 (0.01-0.27)	0.05 (0.00-0.72)

[1]Based on Student's t-tests using log-transformed values.

in plasma; in 1985 the same bird carried only 0.26 ppm. Levels of other organochlorines fluctuated similarly. We found no evidence of a gradual increase in organochlorine residues in individual falcons through time. This was demonstrated by the lack of a significant difference in DDE levels in the plasma of individuals sampled in the same month of consecutive years (Paired t-test: n = 11 First Year Sampled: mean = 0.79 ppm (range = 0.33- 2.65) versus Second Year Sampled: mean = 0.82 ppm (range = 0.44-2.16) $t_{10} = -0.154$ $P = 0.881$).

The correlations between organochlorine residues in the blood plasma of adult peregrines are shown in Table 5. Although weak, significant correlations were found between all compounds except PCBs and Heptachlor Epoxide.

There was some evidence that the body burden of DDE was shed during the breeding season, as the mean level in the plasma of adult females (sample size was too small to make a statistical comparison for adult males) sampled in the summer was significantly lower (38%) than that of the spring samples (Table 6). This was not true of other organochlorines, and the level of Dieldrin in summer samples from females was actually significantly greater than that in spring samples. In general, we did not have enough single season paired samples to evaluate whether seasonal changes in organochlorine residues in the plasma of individuals were significant. In one exceptional case, however, a 4 year-old female, sampled before laying, showed plasma DDE residues of 6.56 ppm. Two months later, after it hatched all four eggs of a

TABLE 7. Geometric mean levels of organochlorine residues in the blood plasma of Peregrine Falcons returning to nesting territories in years following sampling versus those not returning in years following sampling at Rankin Inlet.

Sex/status	*n*	DDE	PCB	Dieldrin	Heptachlor Heptachlor Epoxide
Males returning	12	1.08 (0.28-8.19)	0.22 (0.00-2.25)	0.06 (0.00-0.23)	0.07 (0.02-0.35)
Difference[1] (*P*)		0.307	0.925	0.279	0.068
Males not returning	7	0.66 (0.19-1.73)	0.20 (0.00-2.21)	0.03 (0.00-0.30)	0.03 (0.00-0.15)
Females returning	24	0.72 (0.15-6.56)	0.44 (0.00-3.84)	0.07 (0.01-0.27)	0.04 (0.00-0.72)
Difference[1] (*P*)		0.342	0.407	0.468	0.782
Females not returning	21	0.88 (0.34-2.73)	0.64 (0.18-1.84)	0.08 (0.03-0.21)	0.05 (0.00-0.23)

[1]Based on Student's t-tests using log-transformed values.

TABLE 8. Organochlorine residues in tissues of three adult male Peregrine Falcons found dead in the Keewatin District of the Northwest Territories.

Collection Date	Tissue	DDE	Dieldrin	PCB	Heptachlor Epoxide	Mirex
May 1981 (see Peakall et al., this issue)	Liver	84.20	2.97	207.99	2.98	NA
	Breast Muscle	47.10	1.39	111.00	1.43	NA
May 1987	Liver	12.96	2.84	66.12	1.67	2.61
	Breast Muscle	7.11	1.91	28.43	0.90	1.30
May 1987	Liver	12.77	2.15	13.90	1.18	1.73
	Breast Muscle	8.71	1.39	7.28	0.71	0.83

NA = Levels not available.

clutch, this bird showed plasma DDE residues of 1.10 ppm, a reduction of 83%.

Levels of organochlorines in the blood plasma of adults during summer could not be linked to mortality during the winter (disappearance was assumed to represent mortality : Court et al. 1989). Levels of organochlorines in the blood plasma of adults that did not return in the next breeding season were not significantly different from those of adults returning in the next breeding season (Table 7).

Peakall et al. (this volume) measured organochlorine residues in brain, liver, and breast muscle tissue of an adult male Peregrine Falcon found dead at a nesting territory in Rankin Inlet in 1981. Two other adult male peregrines were found dead (emaciated and frozen) in this region following a spring blizzard in 1987. Although not as polluted as the individual analysed by Peakall et al., both of these specimens carried significant levels of organochlorines. A comparison between organochlorines in tissues of all three specimens is presented in Table 8.

Relationships Between Eggshell Thickness and Residues in Eggs and Plasma

There was a significant negative relationship between eggshell thickness and log DDE residues in egg contents of 50 samples where both shells and contents were available from the same egg (Figure 4). Using clutch means for both DDE residues in egg contents and eggshell thickness, this relationship is also significant ($n = 34$ $y = 0.3447 - 0.0476 \log_x$, $r = -0.53$ $P = 0.001$) (Table 3). For the latter sample, mean DDE in egg contents was 7.57 ppm and mean eggshell thickness 0.303 ± 0.025 mm. A similar relationship existed between shell thickness and PCB residues (Table 3).

Although samples sizes were small, there was a significant negative correlation between the log of blood plasma DDE levels of females sampled before laying and the thickness of their eggshells ($n = 5$ $r = -0.91$ $P = 0.034$). There was no relationship between these variables for females sampled for plasma after laying ($n = 28$ $r = 0.02$ $P = 0.599$). There was a significant positive relationship between log DDE in egg contents and log DDE in blood plasma of the female laying the egg (Figure 5); mean DDE in plasma for this sample ($n = 10$) was 0.90 ppm and mean DDE in the eggs was 8.54 ppm.

Organochlorine Residues in Prey Species

Residues from whole body pools of 11 migratory prey species used by Peregrine Falcons at Rankin Inlet are summarized in Table 9. All species except Snow Buntings (*Plectrophenax nivalis*) contained measurable levels of organochlorine pesticides, and most contained residues of PCB contaminants. Rock Ptarmigan (*Lagopus mutus*), the least

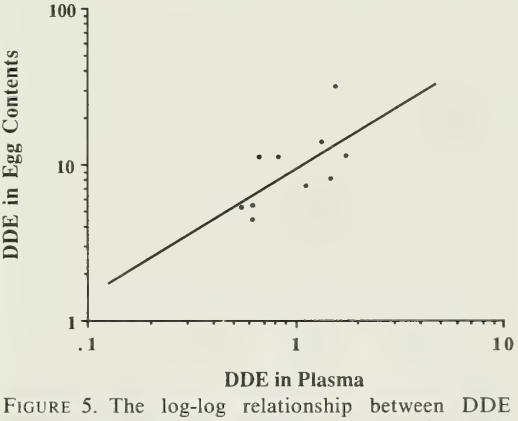

FIGURE 5. The log-log relationship between DDE residues in blood plasma (ppm wet weight) and DDE residues in contents of eggs (ppm wet weight) laid by the same female Peregrine Falcon at Rankin Inlet (log DDE in egg contents = 0.9723 + 0.8506log DDE in plasma $n = 10$ $r = 0.66$ $P = 0.038$).

TABLE 9. Organochlorine residues in representative prey species of Peregrine Falcons nesting at Rankin Inlet.

Species	Pools analyzed (total individuals)	Residues[1]			
		PCB	DDE	Dieldrin	Heptachlor Epoxide
Oldsquaw *Clangula hyemalis*	4(9)	4.21 (0.44-12.42)	0.88 (0.20-3.40)	0.11 (0.00-0.16)	0.02 (0.03-0.59)
Rock Ptarmigan *Lagopus mutus*	5(10)	ND	0.01[2]	0.02[2]	0.01[2]
Semipalmated Plover *Charadrius semipalmatus*	1(10)	1.06	1.11	0.18	0.72
Baird's Sandpiper *Calidris bairdii*	1(4)	0.08	0.26	0.10	0.27
Semipalmated Sandpiper *Calidris pusilla*	1(8)	0.21	0.11	0.04	0.04
Lesser Golden Plover *Pluvialis dominica*	1(5)	0.11	0.91	0.65	1.73
Black Guillemot *Cepphus grylle*	3(10)	0.49 (0.31-0.68)	0.25 (0.19-0.28)	0.03 (0.0-0.04)	0.01 (0.02-0.05)
Horned Lark *Eremophila alpestris*	1(10)	0.07	0.11	0.05	0.01
Water Pipit *Anthus spinoletta*	1(7)	0.23	4.22	0.19	0.15
Lapland Longspur *Calcarius lapponicus*	1(10)	0.02	0.10	0.07	0.01
Snow Bunting *Plectrophenax nivalis*	1(5)	ND	ND	ND	ND

[1]Geometric mean and range are given for samples analyzed in more than one pool
[2]Detected in only one pool
ND = Not detected

migratory of all species analyzed, contained the lowest measured levels of organochlorines. Ocean dwelling species, Black Guillemots (*Cepphus grylle*) and Oldsquaw (*Clangula hyemalis*), showed elevated levels of PCB and DDE residues, with Oldsquaw pools averaging the highest PCB concentrations (4.21 ppm) of all species sampled. Organochlorines were detected in species pools of all shorebird species sampled, with the highest residues recorded in the two plover species. Of the passerines, Water Pipits (*Anthus spinoletta*) contained the highest residue levels, and the exceptionally high DDE concentration in this species (4.22 ppm) was the highest of all prey species tested. Although DDE, PCBs, Dieldrin, and Heptachlor Epoxide were present in the highest concentrations, DDT, DDD, Hexachlorobenzene, BHC, Mirex, and Oxychlordane were also detected in the prey species sampled.

Discussion

The reported variation in reproductive and population status of arctic peregrine populations in recent years makes the results of any detailed inquiry of pesticide pollution in these birds important and, with our study, forces us to address a number of questions: 1) What body of evidence do we have to evaluate the levels of pollution in peregrines nesting in the Keewatin District, and how well do the separate data sets (eggshells, residues in eggs, residues in plasma) support one another? 2) From what we know of pollution in other populations, how severe is the present level of pollution in this population and how do these levels affect the productivity of the Rankin Inlet population? 3) Do prey species contribute significantly to pollutant levels in peregrines on the breeding grounds? 4) Do observations here help to explain variation in reproductive success of falcons nesting at arctic latitudes? 5) Can we predict how populations are likely to respond in the near future, and can we recommend techniques to monitor more effectively changes in these populations?

Eggshell Thinning

DDE-induced eggshell thinning is recognized as the proximate cause of reproductive failure in polluted populations of the peregrine (Ratcliffe 1967, 1970; Hickey and Anderson 1968). For this reason, collections of shells for thickness comparison represent a useful means by which to evaluate potential pollution problems. Our large collection of shell fragments and whole shells provided a representative average eggshell thickness for the Rankin Inlet population and showed that these birds produce shells about 16%

thinner than pre-pesticide eggs for peregrines breeding in the Nearctic. This degree of thinning was roughly similar to thinning percentages recorded for tundra peregrines in Greenland in the 1970s (Walker et al. 1973 - 14.1%) and the 1980s (Falk and Møller 1986 - 14.2%), and Alaska between 1979 and 1984 (Ambrose et al. 1988 - 13.6%). This degree of shell thinning, however, is considerably less than that obtained for tundra peregrines in Ungava in the late 1960s (Berger et al. 1970 - 21.1%).

Hickey and Anderson (1968) concluded that, for a number of bird species, eggshell thinning above 18% is associated with reproductive failure. For the peregrine, a recent review of 30 different studies of pollution in the species showed that populations declined or had been extirpated in every case where shell thinning had exceeded 17% below normal (Peakall and Kiff 1988). By this standard, the high reproductive success in the Rankin Inlet population is explainable in that most pairs produce eggshells that are thicker than critical shell thinning levels. In this population only about 10% of laying pairs failed with egg breakages, but the significantly lower shell thickness of eggs from failed nests (Table 1) supports the conclusion that eggshell thinning was the cause of most of these breakages. Although the high productivity of the study population appears sustained with this degree of eggshell thinning, average shell thickness is dangerously close to critical levels.

Organochlorine Residues in Eggs

Ratcliffe (1970) reported that peregrines in Great Britain, failing with egg breakages, averaged only 13.7 ppm DDE in their eggs. More recently, Peakall et al. (1975) concluded that DDE residues in peregrine eggs averaging 15 to 20 ppm would experience reproductive failures. As peregrines nesting at Rankin Inlet produce eggshells with about 16% thinning, it was not unexpected to find a mean DDE level in the eggs of 7.6 ppm, somewhat below the level considered critical. Nevertheless, 4 (11%) of the 36 clutches in the sample contained eggs with DDE levels over 15 ppm. Of these clutches, two contained eggs that broke during incubation, a third was abandoned, whereas three of the four eggs in the remaining clutch hatched. These observations support our conclusion that some pairs at Rankin Inlet fail each year as a direct result of egg breakages associated with DDE contamination. The most polluted egg in our sample, however, contained 29.27 ppm DDE but was from a pair that fledged three young. This supports the conclusion by Ambrose et al. (1988) that the critical range of 15-20 ppm DDE in eggs (Peakall et al. 1975) should not be construed as so rigid that it can always predict the success or failure of individual eggs.

Relative to most other North American populations sampled in recent years, the mean DDE level in eggs produced by peregrines at Rankin Inlet was low. Enderson et al. (1982), studying peregrines in Colorado and New Mexico, reported a mean DDE level in eggs of 19.6 ppm. In Alberta, over the past two decades, peregrine eggs showed greater than 15 ppm DDE in most samples, and birds in the Yukon produced eggs averaging 18 ppm DDE (Peakall et al., this volume). Ambrose et al. (1988) report a recent mean DDE level of 9.3 ppm in eggs of an Alaskan population of *F. p. tundrius*. Peakall et al. (this volume) found that most eggs for *F. p. tundrius* taken in Canada between 1968 and 1982 showed between 5 and 20 ppm DDE in the contents; most of our samples fall within the lower half of this range. Overall, as we concluded from data on shell thinning, the present high reproductive success recorded for peregrines nesting at Rankin Inlet is understandable in that most birds produce eggs with DDE residues below critical levels.

Mean levels of all other organochlorines found in egg contents were below levels considered critical for the species (Table 2). Maximum recorded levels of Dieldrin, Heptachlor Epoxide, and PCBs, however, were high enough to have affected reproduction of some individuals (see summary in Peakall et al., this volume). Interestingly, levels of many of these compounds were highly correlated, suggesting that individual falcons are exposed to most of these compounds collectively. Similar findings have been documented in other studies of polluted peregrine populations (Enderson et al. 1982, Newton et al. 1989).

The mean level of PCBs in eggs from the study population, 8.74 ppm, was the highest of all compounds, including DDE. This is substantially higher than levels obtained for peregrines nesting in the Rocky Mountains (Enderson et al. 1982: 2.0 ppm) and for tundra-nesting peregrines in Alaska (Ambrose et al. 1988: 2.04 ppm). Peakall et al. (this volume) report generally low levels of PCBs in Canadian populations of *F. p. anatum* and *F. p. tundrius*, but note specific instances where PCB levels in the eggs and tissues of tundra birds are inordinately high.

Our data represent one of the few instances in studies of pollution in the peregrine where the ratio of DDE to PCBs has fallen below 1:1. White et al. (1973) reported some of the highest levels of PCBs in peregrines, with a DDE:PCB ratio of 1:4 for peregrines resident in the Aleutian Islands. Newton et al. (1989) note that British peregrines nesting in coastal areas and feeding on sea birds had very much higher PCB residues in eggs compared with falcons nesting inland. Both

Rankin Inlet and Aleutian Island peregrines feed on seabirds, and it is likely that the elevated PCB residues in their eggs reflect this usage. In our sample of prey species, ocean dwelling species, especially Oldsquaw, contained significant levels of PCBs.

Organochlorine Residues in Peregrine Blood Plasma and Carcasses

The only published information on organochlorine residues in the blood plasma of peregrines comes from a study of pollutants in birds captured while on migration through the United States (Henny et al. 1982, 1988). DDE levels in adult female peregrines captured on the coast of Texas between 1978 and 1980 averaged 0.67 ppm for birds sampled in the spring, and 0.40 ppm for birds sampled in the fall. By comparison, these levels are only about 60% of plasma DDE residues in adult females from Rankin Inlet (spring and summer samples versus spring and fall samples). Henny et al. (1982) concluded, based on an adjustment equation for predicting egg residues from plasma residues (Henny and Meeker 1981), that only 6% of adult birds in their sample would suffer reproductive problems. This equation provided an underestimate of actual pollutant levels in eggs from our study (see below), suggesting that Henny et al. (1982) may have been optimistic in their appraisal of potential pollutant problems. However, residues in plasma from birds nesting at Rankin Inlet were double those studied by Henny et al. (1982), yet these birds fail to show a relatively high rate of reproductive failure. Thus, the average of DDE residues in the blood plasma of peregrines breeding at Rankin Inlet, and that for the birds sampled by Henny et al. (1982), are representative of populations that do not face a critical pollution problem.

Henny et al. (1982) reported that hatching year peregrines, after a single winter in Central and South America, returned to North America with DDE levels in blood plasma as high as most adult birds. This was true also of peregrines breeding for their first time at Rankin Inlet. Males first obtained territories at an average age of three years (Court et al. 1989). Mean levels of plasma residues of DDE in these birds (n = 3) was 0.90 ppm, not substantially lower than that from older adults of the same sex (1.13 ppm, n = 17). A female, first obtaining a territory in this population at three years of age, carried a plasma level of 5.1 ppm DDE (pre-laying), produced four eggs (one containing 24.10 ppm DDE with a shell 25% thinner (0.270 mm) than the pre-DDT average), broke two of them, and abandoned the remainder. This observation supports the findings of Henny et al. (1982) who showed that peregrines can accumulate critical levels of pollutants early in life. Additionally, we found no significant difference and high variability in organochlorine levels in individual peregrines sampled in successive years, demonstrating that these birds do not accumulate residues continuously, but vary in their level of contamination from one year to the next. Indeed, the young female mentioned above returned in the next breeding season carrying plasma DDE levels of only 1.6 ppm (pre-laying), produced a clutch of four eggs, and fledged four young.

Henny et al. (1988) provided an update of their earlier work on organochlorine levels in blood of migrating peregrines and found that adult female peregrines sampled in 1984 (n = 22) contained DDE residues that were 38% lower than birds sampled in 1978-79 (n = 21). Although the authors found that their analyses indicated recent applications of DDT on the peregrine wintering range, they noted a "general downward trend" in DDE contamination. Our body of samples, taken from 1982 to 1986 (n = 84) showed no such trend in DDE levels, and there was no significant difference in plasma DDE levels among all years of the study.

In their study of pollution in migratory peregrines, Henny et al. (1982), found that residues from adult females in fall samples (post-breeding) were about 60% of those in samples taken in spring (pre-breeding). At Rankin Inlet, DDE residues in females captured after laying were about 62% of those captured before breeding. This reduction in residues during breeding supports earlier studies showing that raptors are capable of 'flushing' DDE residues in the lipid of egg yolk. Bogan and Newton (1977), for the European Sparrowhawk (*Accipiter nisus*), and Henny and Meeker (1981), for the American Kestrel (*Falco sparverius*), demonstrated that females may rid themselves of up to 50% of the body burden of DDE by laying one clutch of eggs. Females at Rankin Inlet may also reduce residue levels through excretory routes other than egg laying, as they feed on prey species that are less contaminated than those used on the wintering range or on migration.

There were measurable residues of other pesticides and PCBs in the blood plasma samples, and correlations between these compounds support our earlier conclusion that peregrines are probably exposed to these chemicals collectively. Also, the significantly higher PCB levels in the plasma of female peregrines compared to that of males in the study population suggests different levels of exposure to these compounds. On the breeding grounds, Oldsquaw ducks showed by far the highest levels of PCBs in prey species available at Rankin Inlet and the remains of this species are common at peregrine nests (Bradley 1989). Oldsquaw, averaging 873 g in body weight (Dunning 1984), are by far the heaviest of prey

species taken by this population of falcons and adult male peregrines, averaging only about 600 g in body weight (Court et al. 1988a), probably rarely attempt to take them.

As organochlorine levels in plasma and internal organs of birds are highly correlated (Henny and Meeker 1981), the high levels of such compounds in blood samples from this study, particularly the levels seen in samples from the early spring, raises the possibility of direct mortality through poisoning. Dieldrin, DDE, Heptachlor Epoxide, and PCBs have been implicated as the cause of death in a number of raptor species, including: the Merlin (*Falco columbarius*) (Henny et al. 1976), the Bald Eagle (*Haliaetus leucocephalus*) (Cromartie et al. 1975), the European Sparrowhawk (Newton 1986), and the peregrine (Reichel et al. 1974; Ratcliffe 1980; Peakall et al., this issue). It has been proposed that birds retain these lipid soluble compounds in body reserves and are subsequently poisoned when reserves are suddenly utilized in times of stress, specifically during breeding, the molt, or migration (Bernard 1963). Laboratory observations support this conjecture (Porter and Wiemeyer 1972).

Peregrine Falcons breeding in the Keewatin District of the N.W.T. arrive on the breeding grounds in late May (Alliston and Patterson 1978; Court et al. 1988a), before the majority of their primary prey species (Court et al. 1988a). At this time, weather can be severe and the spectrum of prey species available is limited. In some years of poor spring weather and reduced prey abundance, adults may be forced to use body reserves, resulting in the elevated plasma levels of organochlorines in samples taken at this time. Adult males, with their smaller size (about 66% of the weight of females at Rankin Inlet - Court et al. 1988a) and relatively greater energy demands, might be especially vulnerable to poisoning at this time. Peakall et al. (this volume) conclude that an adult male found dead on territory at Rankin Inlet in the spring of 1981 is likely to have died from organochlorine poisoning (Table 8). Relative to this specimen, however, the residues in the adult birds found dead in the spring 1987 were low, and it is likely that the combination of severe weather and lack of available prey figures as the primary cause of death.

Adult females at Rankin Inlet also show evidence of stress during the breeding season and show a considerable drop in body weight between arrival and the nestling-rearing stage, up to a 20% reduction in some cases (Court unpublished data). It is unlikely that they regain this weight before migration, as they continue to feed young until they leave the area in the autumn (Court et al. 1988a). Considering this, we expected that those adults leaving the breeding grounds carrying the highest levels of organochlorines might be the least likely to survive the wintering season. At Rankin Inlet, however, pesticide residues in plasma of adults during summer appeared to have no bearing on survival in the subsequent winter.

Henny et al. (1982) were able to sample a large number of hatching year peregrines during their first fall migration; DDE levels in blood plasma of male and female juveniles averaged 0.05 ppm and 0.07 ppm respectively. These levels are not appreciably greater than those obtained in the plasma of 3-week-old nestlings at Rankin Inlet, suggesting that there is minimal exposure to these compounds during the first leg of the migration. The levels obtained in the young birds at Rankin Inlet demonstrate, however, that they must retain some residues originally present in the egg yolk, as recorded by Enderson and Berger (1968), and/or they begin accumulating DDE on the breeding grounds during their earliest days of life.

Relationships Between Eggshell Thickness and Residues in Eggs and Plasma

Research at Rankin Inlet represents one of the few studies of pollution in the peregrine where it was possible to collect data on eggshell thickness, organochlorine residues in eggs, and organochlorine residues in the blood plasma of birds producing the eggs. The value of each medium for assessing pollutants in raptors depends, to a large degree, on the strength of the relationships between all media combined. Eggshell thickness, for example, is known to be negatively correlated with DDE content in the eggs (Cade et al. 1971; Lincer 1975). In experiments with falcons in captivity, Lincer (1975) found this correlation to be strong ($r = -0.89$), but with field data for the same species, the best correlation obtained was considerably weaker ($r = -0.40$). Cade et al. (1971), working with wild peregrines, found a significant correlation between eggshell thickness and DDE content in eggs ($r = -0.74$), stronger than that obtained in our sample ($r = -0.60$). Newton et al. (1989), however, obtained a similar correlation coefficient ($r = -0.57$) in a recent review of data from a very large collection of peregrine eggs in Britain. In any case, the correlation between shell thickness and DDE contamination in eggs from field studies is not as strong as one might predict. At best, this correlation can be used only to predict a range of egg residues over which critical eggshell thinning is likely to occur.

Similarly, we found that the relationship between DDE levels in blood plasma and DDE in eggs is not that strong ($r = 0.66$), forcing us to draw a similar conclusion about predictions of pollutant levels in eggs from levels in the blood. Henny and Meeker (1981), however, working with accipiters

and the American Kestrel, found a strong correlation between these variables and have proposed two adjustment equations for estimating organochlorine levels in eggs from residues in blood plasma; one for blood taken before laying ($n = 22$ $r = 0.82$ $y = 3.079x^{1.000}$) and another for post-laying samples ($n = 68$ $r = 0.78$ $y = 6.243x^{1.033}$). Using these equations and the mean DDE residue in plasma of female peregrines from Rankin Inlet, we estimated a mean DDE egg residue of 3.39 ppm (pre-laying equation with spring samples). The post-laying equation (using summer plasma samples) provided an estimate of DDE in the eggs of 4.19 ppm. In reality, the mean DDE level in the sample of eggs from this population was 7.59 ppm, almost double that estimated by the equations of Henny and Meeker (1981). We also checked the accuracy of estimates using a sample where DDE residues were available from plasma and eggs of the same female. Here, each plasma sample was used to calculate an egg DDE level. The mean DDE level in plasma was 0.90 ppm ($n = 10$). The mean for the estimates of DDE in eggs was 5.56 ppm ($n = 10$), slightly more than one-half (65%) the actual mean DDE level in eggs (8.54 ppm $n = 10$). Clearly, residues from our plasma samples and the adjustment equations proposed by Henny and Meeker (1981) provide an underestimate of DDE levels in the eggs of peregrines at Rankin Inlet.

Henny and Meeker (1981) cautioned that the ability to predict accurately egg residues of individuals from plasma is tenuous because of inherent variability, and recommended that estimates be used only to rate the ΣDDT burdens of populations, not individuals, as either low, moderate, or high. Our results suggest, however, that these equations will provide a conservative estimate of pesticide burdens for a peregrine population. We suggest that future field work on the peregrine should involve efforts to obtain larger samples of blood and eggs from the same individuals, possibly contributing to an improvement in our ability to use plasma to predict levels of residues in eggs. Henny (personal communication) has suggested that to further refine this procedure, consideration might be given to body condition (eg: weight) of birds at the time of sampling, as sudden deterioration in condition appears to affect residues in plasma.

Henny and Meeker (1981) stressed that monitoring organochlorines in blood plasma should be viewed as a supplement to existing procedures, and not as an end in itself. They point out, however, that this medium is ideal for establishing trends in pollutant burdens. We concur, and suggest that residues from the plasma samples obtained in our study should be viewed as representative of a polluted, but still productive, population of the peregrine.

Pollutant Levels in Prey and Reproductive Failure

In a recent review of almost all chemical analyses of Peregrine Falcon eggs undertaken in Britain over the last three decades, Newton et al. (1989) concluded that viable populations of this species can exist in polluted environments when geometric mean levels of DDE in eggs are no higher than 15 ppm , shell thinning does not exceed 15-20% below normal, and productivity is greater than 0.6 young per territorial pair. At Rankin Inlet, the geometric mean level of DDE was 7.6 ppm, shell thinning averages 16% below normal, and, in years when poor weather does not affect reproductive success, production averages about two young per territorial pair (Court 1986, Court et al. 1988a). Therefore, despite the fact that birds in our study population produce shells thinned close to critical levels, pollutant and productivity data indicate a viable population.

As the Rankin Inlet population was studied in detail only recently, it is impossible to know whether there existed higher rates of reproductive failure and/or population declines in the past. Greenland populations were largely stable through the 1970s (Burnham and Mattox 1984), when other populations in Alaska and parts of Canada were showing declines (Cade et al. 1971; Cade and Fyfe 1970; Peakall et al. 1975; Fyfe et al. 1976). Present levels of productivity and aspects of the life history of the Rankin Inlet population, most notably the heavy use of tundra-nesting passerines in the diet, closely parallel populations of the peregrine in Greenland. Considering this, we speculate that the population at Rankin Inlet and others in the Keewatin District were probably stable during the last two decades.

Enderson and Berger (1968) were among the first to speculate that some populations of the peregrine in northern areas would be affected by pollutants to a greater degree than others. They suggested that there would exist regional differences in the ratio of migrant to non-migrant prey species, with higher levels of pollutants in peregrine populations sympatric with prey species that winter in areas of high pesticide use. This has been documented in Britain, where peregrines feeding on non-migratory Red Grouse (*Lagopus lagopus scoticus*) in the Scottish Highlands contain only a fraction of the residues found in falcons nesting on the coast (only a few hundred kilometres distant) and feeding on sea birds and waders (Newton et al. 1989).

Springer et al. (1984) found differences in pollutant levels in peregrines in Alaska and Greenland for samples taken between 1977 and 1980, and suggested that the relatively low levels of

pollution and higher reproductive success in the Greenland birds were related to the consumption of proportionately fewer migrant prey species before laying. The authors noted that peregrines in Greenland subsist on migrant passerines to a greater degree than in Alaska, prey species that usually contain substantially lower DDE residues than the aquatic birds taken by Alaskan peregrines (Cade et al. 1968).

We believe that a similar situation exists at Rankin Inlet, where, like Greenlandic peregrines, the bulk of the avian prey taken consists of ptarmigan and tundra-nesting passerines. DeWeese et al. (1986) reviewed studies of the effects of DDE in the diet of raptors and concluded that levels of DDE in prey species above 3.0 ppm (wet weight) are high enough to potentially affect the reproductive success of avian predators such as the Peregrine Falcon. In our sample, only Water Pipits contained DDE concentrations of this magnitude, while ptarmigan and three of the four passerines sampled showed insignificant levels of organochlorines. Water Pipits, however, are by far the least common of passerines available to peregrines at Rankin Inlet. Moreover, they do not arrive in large flocks in the early spring as do the other passerines, so are probably less attractive as prey for peregrines at this time; subjective appraisal of prey remains at nest cliffs in the early spring supports this conjecture. Also, from his analysis of pellets and prey remains collected throughout the breeding season at Rankin Inlet, Bradley (1989) concluded that Horned Larks, Snow Buntings, and Lapland Longspurs comprise the bulk of the passerines taken.

The presence of ground squirrels and microtines in the diet of peregrines at Rankin Inlet (Court et al. 1988a, 1988b) is also noteworthy, as these species would be expected to contain only trace levels of organochlorines and represent a important source of 'clean' food for peregrines in this region. Recent data from Bradley (1989) showed that even in years when rodents are not at peak abundance, mammals constitute as much as one third of the total biomass of prey used by peregrines at Rankin Inlet.

From our sample of prey species, it is apparent that shorebirds and waterfowl at Rankin Inlet carry elevated levels of organchlorines. However, the chronology of the breeding season in this area makes it unlikely that these species contribute much to pesticide burdens of peregrines immediately before laying. For example, in polluted peregrine populations in Alaska, the arrival of falcons on the breeding grounds is thought to be closely synchronized with the arrival of waterfowl (Cade 1960, White 1969). At Rankin Inlet, peregrines arrive on the breeding grounds during the second half of May (Court et al. 1988a), when the only avian prey species available are Rock Ptarmigan and Snow Buntings, species that show no or only trace residues of organochlorines. The mean date of arrival for other passerine species is May 24, that of shorebird species and Oldsquaw is June 6, and Black Guillemots do not arrive on the study area until the third week of June (Court et al. 1988a). Thus, peregrines breeding at Rankin Inlet are not exposed to a wide spectrum of polluted prey species until about two and one-half weeks after they arrive on the breeding area. Quite probably, this period on "clean" food results in a reduction in the average body burden of organochlorines in these birds before laying begins (7 June; - Court et al. 1988a). The reduction in DDE levels in the blood plasma of female peregrines during breeding season supports this conjecture. In experiments with the American Kestrel, Henny and Meeker (1981) recorded a drop of 16.7% in plasma DDE levels after only 2 weeks on clean food; the same birds averaged a 4-5% reduction in plasma DDE in each of 6 subsequent weeks on a pesticide-free diet.

We believe that a combination of diet (a lower proportion of migratory species taken) and the timing of prey use (asynchronous arrival with most contaminated migratory prey species giving two weeks on relatively uncontaminated food before laying) has spared peregrines nesting at Rankin Inlet from widespread reproductive failure in the past. This also explains the present high reproductive success even though these birds continue to face a polluted wintering range. Other arctic populations of the peregrine, particularly those nesting in relatively severe climates with a low proportion of highly contaminated migratory prey species in the diet (for example: those on the Arctic Archipelago, the Keewatin District, and Greenland), most probably continue to reproduce normally for the same reasons.

Recommendations for Future Work

Our study demonstrates that Peregrine Falcons nesting at Rankin Inlet accumulate significant amounts of organochlorine pesticide and PCB residues. Although polluted, this population remains productive, cannot be considered in decline, and is unlikely to show a decline in the next few years. We believe that, in all probability, the same can be said for most other productive tundra-nesting peregrine populations in Canada (Calef and Heard 1979; Kuyt 1980; Bromley 1988). Thus, although the peregrine has been largely extirpated in Canada south of the 60th parallel and east of the Rocky Mountains, viable populations persist in Arctic regions.

Present levels of reproductive success in *F. p. tundrius* leave little room for complacency,

however, as our results suggest that a certain proportion of these birds fail each year as a direct result of organochlorine pollutants. Our data indicate a substantial degree of eggshell thinning in Peregrine Falcons breeding at Rankin Inlet. There is little hope for a deliberate reduction in organochlorine pesticide use in Central and South America in the near future, though forecasts of reduced DDT use are encouraging (Burton and Philogène 1988). There exists the continued threat from Dieldrin and other cyclodiene insecticides (Nisbet 1988), and we have little knowledge of the long term effects of PCBs on wildlife, compounds that continue to increase in concentration in the world's ecosystems. With these facts in mind, we have a solid case supporting the "threatened" status with which wildlife officials now label *Falco peregrinus tundrius*.

Monitoring pollutant levels and population trends in arctic peregrines should continue. Results from this study, namely levels of eggshell thinning, residues in eggs and blood plasma, and pollutants in prey, are representative of a polluted yet still productive population; these data will be of comparative value for future work. Canada's Arctic is so immense and populations of peregrines are so poorly known, that we recommend that future studies of pollutants in this species be conducted in an intensive nature, rather than on an extensive scale as in previous years (Cade and Fyfe 1970; Fyfe et al. 1976). We believe that as much material as possible (eggshells, addled eggs, blood plasma, and prey species) should be collected for analysis on an annual basis from a few discreet, well known populations of this species in the North. Ideally, each study population would use a different spectrum of prey species, improving our understanding of the effects of contaminated prey on local peregrine populations. Results from separate studies could be used to index pollution in the arctic population as a whole.

The same applies to surveys of population size and reproductive success. Our work has demonstrated (Court 1986, Court et al. 1988b) that there can exist natural, profound, short-term variation in population size and reproductive success of tundra-nesting peregrines. Thus, in some areas where peregrine populations are poorly known (ie: most arctic populations of the peregrine in Canada), extensive surveys performed once every five years (Cade and Fyfe 1970; Fyfe et al. 1976; White et al., this issue) are unlikely to always give a clear picture of population trends. Again, we recommend study of a few discreet populations on an annual basis, and that long-term findings on reproductive success and population trends be used as an index of the "health" of the population as a whole. This information, combined with data from pesticide collections made incidentally, would make it possible to assess whether the threat from foreign pollutants is decreasing, or whether the situation is worsening and that active management of arctic populations is needed.

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Residue Levels of Environmental Contaminants in Prey Species of the Peregrine Falcon, *Falco peregrinus*, in Canada

ALAIN BARIL[1], JOHN E. ELLIOTT[1], JAMES D. SOMERS[2] and GARY ERICKSON[3]

[1]National Wildlife Research Centre, Canadian Wildlife Service, Ottawa, Ontario K1A 0H3
[2]Alberta Environmental Centre, Vegreville, Alberta T0B 4L0
[3]Alberta Forestry, Lands and Wildlife, Edmonton, Alberta T5K 2G6

Baril, Alain, John E. Elliott, James D. Somers, and Gary Erickson. 1990. Residue levels of environmental contaminants in prey species of the Peregrine Falcon, *Falco peregrinus*, in Canada. Canadian Field-Naturalist 104(2): 273–284.

The current status of contaminant residues in avian prey species of the Peregrine Falcon in Canada and its significance for the recovery of the raptor population is examined. Levels of contaminants of concern, organochlorine compounds and mercury, in species of prey were obtained for the main part from the Canadian Wildlife Service National Registry of Toxic Chemical Residues and were averaged for each of eleven regions and over a seven year period (1980-1986). Recent data were also made available for prey collected in Alberta. Concentrations of DDE, dieldrin and PCBs can still be found in prey at levels which could be associated with deleterious effects on the reproductive success of nesting peregrines. The species with the highest concentrations were generally those which feed on aquatic organisms (such as herons and grebes), shorebirds and swallows. The data did not allow for analysis of regional differences. Recently collected specimens from southern Ontario and evidence from the United States suggest that certain chemical "hot spots" are still present in North America and may have significant effects on the recovery of peregrine populations. Although the situation regarding organochlorine contamination of the environment has improved since the late 1960s, it is suggested that in planning releases of captive-bred peregrines consideration should be given to potential contamination problems. Monitoring of potential prey species should be carried out in areas where: (1) populations of species likely to have high levels of organochlorine contaminants are present and, (2) organochlorine pesticides were used in large quantities in the past.

Ce rapport discute de la contamination des proies du Faucon pèlerin au Canada et des conséquences pour le rétablissement des populations. Les contaminants d'intérêt sont le mercure et les composés organochlorés tels le DDE, la dieldrine, l'oxychlordane, l'époxide d'heptachlore, l'alpha-HCH, le mirex, l'hexachlorbenzène et les BPC. Les données parviennent, en grande partie, du Registre national des résidus de produits chimiques toxiques et sont rassemblées par région (11 à travers le pays) et par intervalle de temps (1980-1986). Des données plus récentes pour des proies provenant de la Colombie Britannique, l'Alberta, le Nouveau Brunswick et la Nouvelle Ecosse sont aussi incluses. Chez certaines proies, les concentrations de DDE, de dieldrine et de BPC se retrouvent toujours à des niveaux associés à des effets nocifs sur la reproduction des Faucons pèlerins. Les concentrations les plus élevées se retrouvent généralement chez les espèces qui se nourissent d'organismes aquatiques (telles les hérons, les oiseaux de rivage et les hirondelles). La nature disparate des données n'a pas permi l'analyse des différences régionales et temporelles. Certains spécimens provenant tout récemment du sud de l'Ontario et des études menées aux Etats-Unis suggérent l'existence de certaines "régions chaudes" en Amérique du nord. Celles-ci pourraient affecter, à travers la chaine alimentaire, le rétablissement des populations de Faucon pèlerin. Bien que la contamination de l'environnement par les substances organochlorés a diminué depuis la fin des années 1960, on doit toujours tenir compte de ces problèmes durant la planification des programmes de ré-introduction des Faucons pèlerins. Un inventaire minutieux devrait être entrepri dans les régions (1) où des proies du Faucon pèlerin seront probablement contaminées par des substances organochlorés et, (2) où un usage important de pesticides organochlorés a eu lieu dans le passé.

Key words: organochlorine, mercury, Peregrine Falcon, *Falco peregrinus*, birds, residues

In 1975, a survey of breeding populations of the Peregrine Falcon (*Falco peregrinus*) in North America revealed that arctic and boreal populations had declined by at least 50% of their maximum recorded size and that in regions south of the boreal forest, populations of the *anatum* race had declined to the point that it was extirpated from many regions as a breeding bird (Fyfe et al. 1976). Of 1090 known breeding sites of the *anatum* and *tundrius* races in North America only 317 were known or suspected to be occupied in 1975. This decline, observed both in North America and Europe, is now clearly associated with eggshell thinning induced by DDE, a metabolite of the organochlorine insecticide DDT (Peakall and Kiff 1988). Also, in England, the use of cyclodiene insecticides such as aldrin, dieldrin and heptachlor as seed dressings was implicated in the death of peregrines consuming contaminated prey (see Ratcliffe 1980).

In Canada, since 1975, a major effort to reintroduce captive-bred peregrines into their former range has been underway (*see* Holroyd and Banasch, this issue). It was hoped that, since most

organochlorine compounds had been banned or restricted in their use in the late 1960s and early 1970s, the released birds would breed successfully in an environment where levels of contaminants were declining. One major obstacle to this aim, however, is the fact that Peregrine Falcons and many of their prey winter in Central and South America where the use of organochlorine compounds continues. Also, DDE was shown to persist in northern temperate soils for many years at biologically significant levels (Beyer and Gish 1980). In North America, wildlife are still exposed to organochlorine compounds both from recent uses and historical sources (Fleming, Clark and Henny 1983).

Recent surveys show encouraging trends (*see* Murphy; Fyfe and White; this issue). Captive-released peregrines are returning to Canada and in some instances are attempting to breed; however, concerns are still raised about contaminant levels in the food of the birds (Western Raptor Technical Committee 1985). In the United States, where both wild and re-introduced peregrines are making a comeback and in many cases are breeding successfully (*see* Cade and Dague 1986), the concentrations of organochlorine contaminants in many prey species are still at levels which are thought to interfere with reproduction in raptors (DeWeese et al. 1986). In light of the major efforts presently expended by wildlife agencies in Canada towards reintroducing the Peregrine Falcon to its former range, it is now important to evaluate the extent of the exposure of the falcons to organochlorine compounds. It therefore becomes important to: (1) review the data available on current contaminant concentrations in prey species of peregrines in Canada and (2) to assess the potential impact these levels may have on the success of individuals returning to their former habitat. This paper is an abridged version of a more extensive assessment of potential contamination of Peregrine Falcons via their prey (Baril et al. 1989).

Methods

Data

The data analyzed in this review were obtained from two sources: the National Registry of Toxic Chemical Residues (Elliott et al. 1987) and, secondly, from peregrine prey collected in Alberta from 1983 to 1987 by agencies of that province. The choice of avian species considered as prey was based on references provided in the National *anatum* Peregrine Recovery Plan (Western Raptor Technical Committee 1988). Prey from southern Alberta (south of the 54th parallel) were collected from regions which were historically populated by peregrines but where none are now present. These sites were deemed as potential release areas and prey were sampled to evaluate the suitability for release. Prey from northern Alberta (north of the 54th parallel) were sampled in regions where peregrines are now present. Analysis of contaminants in prey was designed to see if these were still a problem.

From the standpoint of the recovery program it would be desirable to focus on residue concentrations in the most common prey species sampled close to historical nest sites, presently occupied nest sites and at release sites. However, because of the vast geographic area covered the data are spotty both in time and space. Therefore we have sorted the residue data for each species by region. While we are concerned mainly with present conditions, the paucity of data on current contaminant levels led to the pooling of all data from 1980 onwards.

The regions were arbitrarily chosen based on knowledge of the distribution of the three races of peregrine, ecozones and areas recognized as major sources of contamination. A total of 11 regions were delineated as shown in Figure 1.

The Contaminants

This study focuses on residue levels of eight persistent organochlorine compounds: DDE, dieldrin, oxychlordane, heptachlor epoxide, alpha-hexachlorocyclohexane (alpha-HCH), hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs) and mirex. Some of these can have serious impacts on avian populations through their effects on reproduction such as eggshell thinning and embryotoxicity (*see* Peakall et al., this issue). Mercury is also included in this review because of its toxicity and close association with human activities.

Details about sample collection, preparation and chemical analysis along with more information on the history and patterns of chemical use can be found in a review of contaminants in Canadian seabirds (Noble and Elliott 1986).

Results

Analysis of the data base reveals that contaminant levels in the prey are available for only six of the 11 regions defined in Figure 1: the Atlantic, Great Lakes, Boreal, Southern Prairies, Rocky Mountains and Eastern Arctic regions. Also, recent residue data (i.e. post 1980) is only available for 29 species, a third of which are common items in the diet of the Peregrine Falcon Finally it should be noted that different tissues were analyzed in different species: eggs were collected for some, while for others, muscle or whole body samples were analyzed for contaminants. All contaminant concentrations are expressed on a wet weight basis.

FIGURE 1. Map of Canada showing the 11 regions selected for calculating regional averages. (1) Atlantic; (2) Great Lakes; (3) Boreal; (4) Eastern Arctic; (5) Southern Prairies; (6) Northern Prairies; (7) Central Arctic; (8) Pacific Coast; (9) Rocky Mountains; (10) Western Arctic; (11) Yukon.

The significance to Peregrine Falcons of contaminant levels in their prey in Canada is difficult to establish for most of the compounds discussed here. Except for DDE, dieldrin and PCBs, the effects on reproduction of dietary intakes for the other contaminants are not well studied (*see* Peakall et al., this issue). Table 1 summarizes the results by identifying species which show contaminant concentrations exceeding specific levels. For DDE, dieldrin and PCBs those levels were chosen on the basis of established toxicological effects. In the case of the other compounds, the levels were chosen arbitrarily and correspond to the highest range of concentrations measured (on a logarithmic scale).

For DDE, ten species out of 29 show levels in eggs, muscle or whole body samples exceeding 1 ppm, the highest mean value being 4.03 ppm in eggs of Red-necked Grebes. These levels are significant and a cause for concern as it is suggested that, in the breeding season, peregrines feeding on prey exceeding about 1 ppm DDE could be expected to lay eggs with shells thinned by more than 7% (*see* Enderson et al. 1982). Although DeWeese and co-workers (1986) cite a DDE concentration in food of about 3 ppm as causing significant eggshell thinning (10-28%) and reproductive failure, a more conservative value of 1 ppm is used here as a cut-off point. Body burdens of about 1 ppm were found in American Robins (2.2 ppm), Western Meadowlarks (1.2 ppm), Dunlin (0.7 ppm) and Brewer's Blackbird (0.9 ppm). American Kestrel, Leach's Storm Petrels and Eared Grebes had levels in eggs close to 1 ppm. While peregrines do not consume the eggs of these species, the DDE contents reflect levels in the whole body approximately two times those in egg according to ratios based on experimental

TABLE 1. Mean levels (standard deviation No. of values averaged) of contaminants in egg, muscle or whole body in peregrine prey species. Only those means which exceeded specified threshold values are shown (see text). Blanks signify that the mean was lower than the threshold values and NA indicates that no values were available.

	Contaminant (Theshold Value)									
Tissue Species Region	DDE (> 1.0 ppm)	Dieldrin (> 0.1 ppm)	Oxychl. (a) (> 0.1 ppm)	HE (b) (> 0.01 ppm)	alpha-HCH (> 0.01 ppm)	HCB (> 0.01 ppm)	PCBs (c) (> 10.0 ppm)	PCBs (c) (> 1.0 ppm)	Mirex (> 0.1 ppm)	Mercury (> 0.1 ppm)
Eggs:										
Red-necked Grebe										
Southern Prairies	4.03 (4.02 23)	0.11 (0.137/24)	0.14 (0.12/23)	0.08 (0.09/22)		0.108 (0.108/24)	11.9 (13.2/24)		0.38 (0.45/22)	0.11 (0.03/19)
Western Grebe										
Rocky Mountains	1.74 (2.74 9)			0.02 (0.01/9)		0.017 (0.004/9)		2.26 (1.9/9)		
Black-crowned Night Heron										
Great Lakes	3.22 (1.88/23)	0.19 (0.36/23)	0.14 (0.12/23)	0.04 (0.02/23)		0.054 (0.095/24)	25.0 (11.5/23)		NA	NA
Eared Grebe										
Southern Prairies										
Leach's Storm Petrel										
Atlantic				0.02 (0.004/6)		0.062 (0.033/5)		2.32 (1.55/5)		0.41
American Kestreel										
Rocky Mountains				0.02 (0.017/10)		0.011 (0.006/10)				NA
Muscle:										
Greater Scaup										
Great Lakes					NA	0.012		8.75		NA
Lesser Scaup										
Great Lakes					NA	0.011		9.75	NA	NA
Mallard										
Great Lakes					NA			1.28	NA	NA
Bufflehead										
Great Lakes	1.56			0.01	NA	0.029	44.4		0.13	NA
Gadwell										
Great Lakes					NA					NA
Blue-winged Teal										
Southern Prairies	1.76			0.01	NA					NA
Whole Body:										
Killdeer										
Great Lakes	1.17	0.47		0.03	0.01					0.14
Southern Prairies				0.02	0.01					0.12
Semipalmated Sandpiper										
Great Lakes					0.02	0.012				0.14
Atlantic				0.02 (0.014/2)	0.02 (0/2)	0.014 (0.009/3)				
Central Arctic				0.03	0.01	0.022				0.40
Spotted Sandpiper										
Atlantic				0.01 (0.004/15)		0.018 (0.046/15)		1.95 (2.18/15)		0.32 (0.29/15)

TABLE 1. *Concluded*

Tissue Species Region	Contaminant (Theshold Value)									
	DDE (> 1.0 ppm)	Dieldrin (> 0.1 ppm)	Oxychl. (a) (> 0.1 ppm)	HE (b) (> 0.01 ppm)	alpha-HCH (> 0.01 ppm)	HCB (> 0.01 ppm)	PCBs (c) (> 10.0 ppm)	PCBs (c) (> 1.0 ppm)	Mirex (> 0.1 ppm)	Mercury (> 0.1 ppm)
Semipalmated Plover										
Central Arctic		0.21		0.03	0.04	0.013		1.14		0.13
Atlantic		0.63		0.08		0.013				
Dunlin										
Central Arctic				0.02	0.02	0.021				0.18
Willet										
Southern Prairies				0.01	NA					NA
Bank Swallow										
Boreal	1.65	0.11		0.02	0.03	0.025		1.00		0.23
American Robin										
Rocky Mountains	2.2 (d)									
Atlantic	1.00 (0.89/2)		0.11 (0.071/2)	0.02 (0.028/2)	0.015 (0.007/2)					
Boreal					0.01				0.10	
Western Meadowlark										
Rocky Mountains	1.2 (d)	NA					NA	NA	NA	NA
Brewer's Blackbird										
Boreal					NA	NA			NA	NA
Southern Prairies				0.02	NA	NA			NA	NA
Red-winged Blackbird										
Atlantic									NA	0.10 (0.03/2)
Great Lakes								1.00 (1.0/2)	NA	0.35
Southern Prairies				0.02 (0.028/2)					NA	0.10
Common Grackle										
Boreal					0.01					0.51
Lapland Longspur										
Central Arctic					0.01	0.010				0.23
Horned Lark										
Central Arctic					0.02					0.10
Northern Flicker										
Boreal					0.01				0.16	0.10
Atlantic										0.10
Bobolink										
Atlantic										0.10 (0.08/2)
Rock Doves										
Great Lakes										
Eared Grebe										
Southern Prairie	2.02			0.01	NA	0.013			NA	NA

[a]oxychlordane
[b]heptachlor epoxide
[c]1:1 ratio mixture of Arocolor 1254 and Aroclor 1260 (see text)
[d]single pooled sample collected at Vasseux Lake, British Columbia (courtesy of W. T. Munro, Ministry of the Environment and Parks, Wildlife Branch, Province of British Columbia)

work with American Kestrels (Wiemeyer et al. 1986). This would suggest that the eggs of Red-necked Grebes sampled in the southern prairies came from birds with body burdens possibly as high as 8 ppm DDE.

Dieldrin concentrations exceeding 0.1 ppm are present in only five species (28 analyzed) with the highest recorded in Semipalmated Plovers at 0.63 ppm (Table 1). Studies have shown that dieldrin may lead to eggshell thinning in Mallards at dietary concentrations of 1.6 ppm, increased embryo death in Grey Partridges at 3 ppm and decreased hatchability in Pheasants at 10 ppm (*see* Jefferies 1973); more recent work shows that dietary levels of 0.5 ppm dieldrin do not reduce breeding success in Barn Owls in spite of a slight reduction in eggshell thickness (Mendenhall et al. 1983). It should also be noted that in those Owls, carcass residues averaged over 9 ppm. Such levels in the brain are associated with dieldrin-induced starvation in Brown-headed Cowbirds (Heinz and Johnson 1981). While levels above 0.1 ppm in prey are not widespread, dieldrin has the same bioaccumulatory potential as DDE (Kan 1978) and its presence may still be of concern in certain regions and prey species.

Twelve species (28 analyzed) have levels of PCBs (measured quantitatively as the 1:1 ratio of Aroclors 1254 and 1260) exceeding 1 ppm with three species showing levels over 10 ppm. Studies on the effect of PCBs on avian reproduction have shown that, in the chicken, dietary concentrations of 10 ppm of Aroclor 1248 caused severe embryonic mortality and concentrations of 5 ppm of Aroclor 1254 decreased egg production (*see reviews in* Peakall 1975, 1986). Hatchability was markedly reduced in Ring Doves fed 10 ppm of Aroclor 1254 (Peakall and Peakall 1973); this effect was ascribed to decreased parental attentiveness. Diets containing 3 ppm Aroclor 1248 eight weeks prior to egg laying did not perceptively affect reproduction in Screech Owls (McLane and Hughes 1980): the number of eggs laid, eggs hatched, young fledged, and eggshell thickness were not affected. These studies show that while species differed substantially in their susceptibility to PCBs and that different congeners differ appreciably in their effects, dietary total PCB levels below 5 ppm do not appear to affect reproduction in birds (*see* Peakall 1986). Of the peregrine prey analyzed, only three duck species collected from the Great Lakes show tissue levels exceeding this value. Concentrations of 25 and 11.9 ppm in the eggs of Black-crowned Night-Herons from the Great Lakes and Red-necked Grebes from the prairies, respectively, are difficult to interpret with regard to their significance to peregrines.

Oxychlordane did not exceed 0.1 ppm in any species (28 analyzed) other than in the eggs of Red-necked Grebes and Black-crowned Night-Herons where they averaged 0.14 ppm and in the American Robin (0.11 ppm). While 50% of Starlings dosed with 1.5 ppm oxychlordane in their diet died within 60 days (Stickel et al. 1979) those dietary levels are two orders of magnitude greater than the concentrations found in the prey collected in Canada. It is not known what effects such low dietary concentrations may have on peregrines.

Similarly, concentrations of heptachlor epoxide were generally low (< 0.1 ppm) in all prey sampled (29 analyzed) and the consequences to peregrines of dietary exposure to these levels are not thought to be significant. Average residues of heptachlor epoxide in the brains of birds fed dietary levels of 50 ppm of heptachlor ranged from 13 ppm in Starlings to 20 ppm in Red-winged Blackbirds; time to 50% mortality in these two species were 9 and 20 days respectively (Stickel et al. 1979). Alpha-HCH concentrations (20 species analyzed) never exceeded 0.1 ppm and the bioaccumulation potential of this compound is low (Kan 1978).

HCB concentrations (28 species analyzed) exceeded 0.1 ppm only in eggs of Red-necked Grebes which had a mean of 0.11 ppm and in the liver of a Bufflehead (0.176 ppm). While low, the significance of these concentrations to the peregrines is not known. Based on an egg injection study, the LD_{50} of HCB to Herring Gull embryos was calculated to be 4.3 ppm (Boersma et al. 1986).

Four species out of 22 analyzed for mirex had levels exceeding 0.1 ppm, the highest average concentration found in the eggs of Red-necked Grebes (0.38 ppm). Although generally low, the significance to peregrines of these concentrations in prey is not known.

More than three-quarters of the species analyzed for total mercury (18 analyzed) showed levels above 0.1 ppm with the highest value of 0.51 ppm found in the Common Grackle. Toxicologically, methylmercury (MeHg) is the most bioavailable and significant form of mercury. A recent review on the chronic toxicity of some metals to birds (Scheuhammer 1987) suggests that methyl mercury levels greater than 1 ppm dry weight (D.W.) in the diet have reproductive effects. Pheasants (*Phasianus colchicus*) fed a diet containing 2-3 ppm (D.W.) MeHg for 12 weeks showed a significant decrease in the hatchability of eggs (Fimreite 1971). Reduced egg output and hatching success were observed in Mallards dosed with dietary levels of 3 ppm (D.W.) methylmercury (Heinz 1974). Diets containing 1.1 ppm inorganic Hg caused damage to various cell types in the

TABLE 2. Mean organochlorine residues (ug/g) in whole body homogenates of peregrine prey collected in Alberta (1983-1987) (N = number of pooled samples per avian family).

Family	N	HCB	alpha-HCH	DDE	Oxychl.[1]	HE[2]	Dieldrin	Mirex	PCB
Avian Families Associated with Aquatic Habitats									
Southern Alberta 1983-1985									
Podicipedidae	2	0.028	0.002	2.8	0.021	0.001	0.001	0.014	0.34
SD		0.007	0.001	3.01	0.008	0	0	0.001	0.01
Anatidae	13	0.056	0.001	1.75	0.01	0.013	0.005	0.001	0.66
SD		0.19	0.004	5.77	0.021	0.041	0.015	0.002	1.93
Rallidae	1	0.001	0.001	0.04	0.003	0.001	0.007	0.002	0.05
Charadriidae	5	0.017	0.003	2.88	0.03	0.072	0.453	0.03	0.22
SD		0.03	0.003	2.44	0.028	0.089	0.603	0.045	0.31
Scolopacidae	7	0.006	0.001	2.84	0.011	0.103	0.06	0.06	0.88
SD		0.011	0.001	2.5	0.007	0.216	0.055	0.055	1.6
Laridae	11	0.043	0.001	2.1	0.018	0.045	0.077	0.001	2.31
SD		0.126	0.001	2.46	0.028	0.069	0.126	0.001	2.58
Alcedinidae	1	0.011	0.017	0.6	0.177	0.032	0.054	0.054	1.59
Hirundinidae	5	0.005	0.009	1.37	0.019	0.044	0.013	0.039	0.42
SD		0.005	0.008	0.93	0.018	0.059	0.013	0.039	0.32
Northern Alberta 1986-1987									
Anatidae	11	0.009	0.005	0.86	0.019	0.019	0.015	0.002	0.5
SD		0.019	0.009	2.24	0.024	0.025	0.024	0.003	0.54
Rallideae	2	0.001	0.001	0.13	0.012	0.009	0.029	0.001	0.31
SD		0	0	0.07	0.006	0.006	0.004	0	0.27
Charadriidae	1	0.001	0.001	1.52	0.045	0.261	0.058	0.005	0.64
Scolopacidae	6	0.001	0.001	0.3	0.009	0.017	0.049	0.008	0.37
SD		0	0	0.41	0.007	0.015	0.062	0.018	0.3
Laridae	12	0.081	0.001	1.59	0.03	0.109	0.165	0.018	1.3
SD		0.241	0	1.22	0.02	0.132	0.214	0.018	0.69
Avian Families associated with Terrestrial Habitats									
Southeastern Alberta 1983-1985									
Phasianidae	1	0.001	0.001	0.004	0.001	0.001	0.002	0.003	0.05
SD									
Columbidae	2	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.03
SD		0	0	0.002	0	0	0	0.001	0.04
Picidae	1	0.001	0.001	0.03	0.011	0.008	0.007	0.002	0.05
Corvidae	2	0.01	0.002	0.08	0.006	0.065	0.006	0.002	0.2
SD		0.001	0	0.009	0.004	0.083	0.001	0	0.21
Mimidae	1	0.002	0.004	0.051	0.008	0.015	0.006	0.002	0.05
Turdidae	10	0.003	0.004	0.152	0.017	0.039	0.062	0.002	0.06
SD		0.002	0.003	0.142	0.017	0.073	0.158	0.001	0.04
Sturnidae	1	0.013	0.005	0.983	0.009	0.007	0.036	0.002	0.05
Ploceidae	1	0.005	0.001	0.002	0.001	0.001	0.001	0.002	0.05
Icteridae	10	0.001	0.001	0.186	0.003	0.006	0.002	0.001	0.13
		0.001	0.001	0.309	0.002	0.004	0.003	0.001	0.23
Fringillidae	3	0.017	0.002	0.142	0.006	0.02	0.003	0.001	0.04
SD		0.027	0.001	0.1	0.006	0.025	0.003	0.001	0.02
Passerines	3	0.003	0.008	0.106	0.003	0.004	0.002	0.001	0.06
SD		0.004	0.007	0.098	0.004	0.005	0.003	0.001	0.01
Northern Alberta 1986-1987									
Tetranidae	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.05
Picidae	4	0.001	0.001	0.194	0.041	0.029	0.016	0.01	0.21
SD		0	0	0.158	0.07	0.031	0.017	0.017	0.14
Turdidae	1	0.001	0.001	0.171	0.012	0.01	0.005	0.012	0.38
Icteridae	3	0.001	0.001	0.259	0.008	0.008	0.005	0.004	0.26
SD		0	0	0.165	0.008	0.002	0.006	0.006	0.14
Passerines	4	0.001	0.001	0.158	0.011	0.007	0.003	0.001	0.19
SD		0	0	0.187	0.008	0.005	0.002	0	0.13

[1]oxychlordane
[2]heptachlor expoxide

kidneys of juvenile Starlings (Nicholson and Osborn 1984). Although the levels reported in prey of falcons in Canada represent total mercury and not the organic fraction, the evidence presented here suggests that present levels of mercury in Canadian prey may exceed, in some cases, the threshold above which symptoms of toxicity may appear in their avian predators. The levels reported here are similar to those observed in peregrine prey in northern Sweden (Lindberg and Odsjo 1983). These authors concluded that the reproductive output of the peregrines feeding on these birds had not been affected by the mercury content. It should be noted, however, that there is much variability between bird species in their sensitivity to mercury (Scheuhammer 1987). Barr (1986) found that reproduction in Loons breeding in Northwestern Ontario was impaired at mercury concentrations of 0.3-0.4 ppm wet weight in fish and invertebrate prey.

It appears that the nine contaminants discussed here were detected in most of the prey species analyzed. While for most contaminants concentrations are low, three compounds are found at levels high enough to be of some concern for the health of Peregrine Falcons. Birds frequently consuming prey with the higher DDE, dieldrin or PCB levels recorded in some specimens may be exposed to levels which could diminish reproductive success. In addition, the effects of chronic exposure to low concentrations of mixtures of different organochlorine compounds are not known.

Levels of organochlorine contaminants in whole body homogenates of peregrine prey collected in Alberta between 1983 and 1987 are summarized in Table 2. The data were averaged by avian family and are presented by habitat and geographic region. It appears that residue levels are on average higher in birds belonging to families associated with aquatic habitats and that concentrations were usually higher (except for heptachlor epoxide and HCB) in southern Alberta than in the northern half of the province. It should be noted, however, that the northern birds were collected in 1986 and 1987 whereas the southern birds cover an earlier period from 1983 to 1985. Also, the southern Alberta Anatidae included a Red-breasted Merganser which contained 20.9 and 7.1 ppm whole body of DDE and PCB respectively; when excluded from the data, the arithmetic means for this family are 0.15 ppm DDE and 0.14 ppm PCB. The highest mean levels reached in families associated with aquatic habitats are similar to those obtained from the National Registry. In southern Alberta, shorebirds of the family Scolopacidae, gulls (Laridae) and one Belted Kingfisher (Alcedinidae) showed the highest average levels for many contaminants. In northern Alberta, Killdeers (Charadriidae) and again gulls (Laridae) had the highest mean concentrations.

Discussion

Whereas most organochlorine compounds were detectable in practically all prey samples analyzed, only a few species, Bank Swallows and certain species associated with aquatic habitats, showed high levels for a number of substances. The eggs of Red-necked Grebes and Black-crowned Night-Herons, the muscle of Bufflehead and whole bodies of Killdeer and Semipalmated Plovers showed the greatest variety of contaminants (see Table 1) and often the highest levels. The Dunlin, Semipalmated and Spotted Sandpipers may, to a lesser degree, be included into this group. Contaminant levels in the eggs of Red-necked Grebes from Alberta and of Black-crowned Night-Herons from the Great Lakes, and in muscle of one Bufflehead from Lake Ontario were often among the highest recorded for many of the compounds. It should be noted that the highly contaminated Bufflehead (pool of two birds) were found dead on the shores of Windemere Basin in Hamilton Harbour, one of the most polluted sites on Lake Ontario.

These findings are in agreement with other studies showing that, among the prey of Peregrine Falcons, aquatic species, shorebirds and aerial insectivores (i.e. swallows) contained the greatest variety and levels of organochlorines in the western United States (DeWeese et al. 1986) and of PCBs, DDT and mercury in northern Sweden (Lindberg et al. 1985). The more extensive collection of birds sampled and analyzed in Alberta supports these trends. The plover, sandpiper and gull families showed consistently higher contaminant levels than other families for a number of compounds. Grebes showed relatively high levels of DDE. The studies cited above and the results presented here probably reflect the large bioaccumulation and biomagnification potentials of aquatic food chains. In particular, the habit of shorebirds, grebes and herons of feeding in coastal areas and estuaries during migration, and in their winter range, makes them particularly susceptible to large inputs of persistent contaminants still present in sediments (White et al. 1983).

The hypothesis that migrant prey accumulate most of their body burdens of organochlorines in Central and South America could not be tested with the data at hand. Nevertheless this hypothesis is supported by studies of contaminants in the prey of Peregrine Falcons (DeWeese et al. 1986; Lindberg et al. 1985; Enderson et al. 1982; Fyfe et al. this issue) showing higher levels of organochlorine compounds in migrant than in resident species. Henny et al. (1982), analyzing blood

samples of migrating Falcons, found that juvenile peregrines migrating south of the United States accumulated most of their pesticide burden during their first winter in Latin America. It is therefore likely that prey migrating to the same wintering grounds also accumulate some organochlorine contaminants during their stay.

This hypothesis, however, need not be the only explanation of the high levels shown here in shorebirds, herons and grebes. The species showing some of the highest levels of contaminants in eggs, the Red-necked Grebe, does not migrate south of the United States. In the past nine years, evidence has grown concerning the presence of North American "hot spots" contributing to the contamination of birds by organochlorine compounds. Shorebirds sampled in the fall and winter months of 1979-1980 on mudflats at the outlets of agricultural drains along the south Texas coast were found to accumulate DDE during their stay to levels known to cause reproductive impairment (White et al. 1983). Wintering shorebirds collected from western Washington and at one site along the California coast between 1980 and 1983 showed highly variable whole body levels of DDE (Schick et al. 1987). The birds showing high levels do not migrate to Latin America thereby indicating the presence of "hot spots" somewhere along the Pacific Coast of North America. A study of DDE and DDT contamination of prey species of the Peregrine Falcon in California and western Texas between 1980 and 1983 showed exceptionally high levels of DDE in the majority of Texas samples and a few of the California samples (Hunt et al. 1986). However, recent illegal uses or transport by birds migrating from Latin America were discounted as sources since p,p'-DDT was not detected in these samples. The authors suggested that the use of the pesticide Kelthane, a miticide containing the active ingredient dicofol, was probably the source of the contamination. Experiments have shown that, in Mallard Ducks, DDE is metabolically derived from technical Kelthane and that most of this metabolically formed DDE was derived from chloro-DDT (Risebrough et al. 1986). The latter was present as an impurity in the pesticide (2.6 to 3.0%) whereas p,p'-DDT was below the detection limit. It should be noted that the U.S. E.P.A. had ordered DDT-related contaminants in Kelthane reduced to less than 0.1% by the end of 1988 (Dolan 1986 *in* Schwarzbach et al. 1988).

One hypothesis receiving more attention lately is that present contamination of wildlife may be attributed to past applications of technical DDT at very high rates in certain agricultural settings. Blus et al. (1987) analyzed wildlife samples collected between 1979 and 1983 in the vicinity of fruit orchards in central Washington where technical DDT had been applied at rates of 56 to 73 kg/ha, with some orchards receiving as much as 1000 kg/ha over the total period ending in the late 1960s to early 1970s. The study showed variability in the concentrations of DDT-related compounds measured with some levels as high as 150 ppm DDE and 13 ppm DDT in the brain of an American Robin found dead. These concentrations are within the lethal range. Although the data were not adequate to determine the exact source of the contamination, the presence of relatively high concentrations of contaminants in resident species suggests local sources. As there was little evidence of recent illegal uses of technical DDT or of applications of dicofol, the authors suggested that residues in certain samples may have originated from previous legal applications. Low DDE:DDT ratios (i.e. < 10) were common but do not necessarily indicate recent applications. The authors cited studies which indicated that once an initial phase of rapid dissipation due to volatilization had passed, DDT and metabolites were estimated to have half-lives as high as 57.5 years and that the half-lives increased with concentration. In one case, soil samples taken in 1985 in California, many years after the last applications, revealed DDT residues exceeding concentrations of DDE in most samples (Mischke et al. 1985 *in* Blus et al. 1987).

For Canada, the data presented here may suggest the presence of similar "hot spots". With regards to regional distribution of contaminants in prey, most compounds were found in all six regions. Comparisons among regions are difficult to make since different species were collected in each region. Nevertheless the samples with the highest concentrations were usually collected from either the Great Lakes or the Southern Prairie regions. The data did not permit discrimination among the various hypotheses about the source of the contamination. Shaw (1983) found in the analysis of eggs and nestlings of Tree Swallows nesting at various sites in Alberta in 1978 and 1979 that nestlings showed higher body burdens of DDE and PCBs than the eggs. This suggests that Tree Swallows were still obtaining some of their organochlorine burdens in Canada. Recently analyzed egg samples from Starlings and American Kestrels collected in Ontario by the Canadian Wildlife Service showed high levels of DDE at the Niagara collection site (10.8 ppm wet weight for American Kestrels and 18.9 ppm for the Starlings). These values are higher than the highest levels recorded in the 1979 whole body samples of Starlings analyzed as part of the United States Fish and Wildlife Service nationwide monitoring of organochlorine residues (Cain and Bunck, 1983). Since it is thought that these birds living in

southern Ontario may not be migrating during the winter, the concentrations in the eggs may reflect the presence of local sources of DDE.

Published reviews on contaminant levels in other Canadian bird species which are prey of peregrines show a general decline in residues since the late 1970s. In the Canadian Great Lakes, trends indicate a general decline of DDT, DDE, PCB, mirex, HCB and dieldrin between 1974 and 1979 in the eggs of Herring Gulls (Mineau et al. 1984). While relatively high in 1979 (< 10 ppm DDE; < 80 ppm PCBs), levels were decreasing and reflected severe restrictions on the use of certain pesticides and the production of PCBs in the late 1960s and early 1970s. Residues of DDE in Caspian Terns decreased from a mean of 13.8 to 5.2 ppm (wet weight) between 1972 and 1981 (Struger and Weseloh 1985). Reductions in contaminant levels in the Great Lakes is thought to have contributed to a 56% annual increase in Double-crested Cormorant populations between 1974 and 1982 (Price and Weseloh 1986).

Noble and Elliott (1986) reviewed trends in the level of contaminants in Canadian seabirds between 1968 and 1985. Some of the species analyzed from the West Coast are important components in the diet of Peregrine Falcons of the *pealei* race. Eggs of Leach's and Fork-tailed Storm Petrels sampled on the West Coast in the 1980s showed levels of DDE just slightly below or above 1 ppm; concentrations of other organochlorines were very low. Overall, the authors found that on the Pacific Coast most contaminants declined in seabirds between 1970 and the 1980's, especially DDE and PCBs. A more detailed study of organochlorine contamination in seabird eggs from the west coast (Elliott et al. 1989) confirmed the trend but showed that eggs of seabirds foraging offshore of British Columbia had higher levels of DDE and HCH than ecologically similar Atlantic coast birds (*see* Pearce et al. 1989). This may point to continued use of DDT and HCH in Asia. Eggs of seabirds from inshore locations on the Pacific coast were less contaminated than their counterparts on the Atlantic coast.

We can conclude from this analysis that the contamination profiles of several prey species of the Peregrine Falcon in Canada indicate that in some instances contaminant levels exceed those which can cause toxic effects in raptors. More specifically, contaminants such as DDE, dieldrin and PCBs are of concern as well as prey species associated with aquatic habitats. The spotty nature of the database and the geographic and temporal spread of prey collections put severe limitations on the interpretation of the results. This, along with the toxicological concerns outlined above warrant more comprehensive surveys near major release sites, especially in light of the possible existence of North American "hot spots" of organochlorine contamination.

In spite of these concerns it should be noted that the most recent evidence indicates a recovery of Peregrine Falcon populations is taking place. Declining organochlorine levels seem to have been a crucial factor in the recovery of this species.

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Organochlorine Residues in Potential Prey of Peregrine Falcons, *Falco peregrinus*, in Latin America

RICHARD W. FYFE[1], URSULA BANASCH[2], VIRGILIO BENAVIDES[3], NANCY HILGERT DE BENAVIDES[4], ANTHONY LUSCOMBE[5], and JULIO SANCHEZ[6]

[1]Box 3263, Fort Saskatchewan, Alberta, Canada, T8L 2T2
[2]Canadian Wildlife Service, Twin Atria Bldg., 4999-98 Ave, Edmonton, Alberta, Canada, T6B 2X3
[3]Cassila 9068 Sc. 7 Q, Quito, Ecuador
[4]Cassila 9068 Sc. 7 Q, Quito, Ecuador
[5]Atahualpa 335, Lima 18, Peru
[6]Museo Nacional de Costa Rica, Apartado 749, San Jose, Costa Rica

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We collected migrant and resident prey of Peregrine Falcons in Suriname, Peru, Ecuador, and Costa Rica to determine levels of organochlorine contamination. Resident species usually showed higher DDE levels than migrants, and carnivorous and insectivorous species showed higher DDE levels than omnivorous and granivorous species. Samples from Peru and Ecuador showed the highest organochlorine residue levels.

Nous avons recueilli des proies migratrices et locales de Faucons pèlerins à Suriname, au Pérou, en Équateur et à Costa Rica afin de déterminer les niveaux de contamination aux organochlorés. Les espèces locales contenaient en général des niveaux de DDE plus élevés que les espèces migratrices, et les espèces carnivores et insectivores présentaient des niveaux plus élevés de DDE que les espèces omnivores et granivores. Des échantillons prélevés au Pérou et en Équateur contenaient les plus hauts niveaux de résidus organochlorés.

Key Words: Peregrine Falcon, *Falco peregrinus anatum*, pesticides, Suriname, Peru, Ecuador, Costa Rica.

The decline of Peregrine Falcons (*Falco peregrinus*) in western and northern Canada correlates with the elevated residue levels of organochlorine pesticides in their tissues (Enderson and Berger 1968; Enderson et al. 1968; Berger et al. 1970). Routine pesticide analyses of prairie birds, specifically of Peregrine Falcon prey, showed organochlorine and heavy metal residues in tissues of most species analyzed (Fimreite et al. 1970; Enderson et al. 1982; Baril and Elliott 1990; Peakall et al. 1990). Any whole body DDE residue level in prey in excess of 1.00 ppm wet weight may yield elevated residue levels in Peregrine Falcons consuming such prey during the breeding season (Enderson et al. 1982).

In both Canada and the United States, peregrine population declines and their lack of breeding success coincided with various aspects of pesticide use during the 1960s and early 1970s. Indeed, DDE contamination was deemed the primary cause for the decline of the anatum subspecies of the Peregrine Falcon (*Falco peregrinus anatum)* (Cade et al. 1971; Peakall 1976), resulting in either the deregistration or severe restriction of the registered uses of organochlorines. Researchers expected these actions to produce dramatic decreases in pesticide residue levels, both in the Peregrine Falcon and its prey.

The listing of *F. p. anatum* as endangered (King 1981), because of its extensive and severe decline, led to captive breeding attempts, both in North America (Cade and Temple 1977; Weaver and Cade 1974; Fyfe 1975; Fyfe 1976) and in Europe (Lindberg 1985; Saar 1985). These programs succeeded; by 1975 the first captive-raised peregrines were released into the wild. Initial Canadian experimental releases, both in urban and rural locations in Alberta, succeeded. Below normal productivity by these birds confirmed suspicions that contamination problems still persisted (Fyfe et al. 1977; Erickson personal communication).

Analyses of unhatched eggs from the Alberta populations indicated continuing accumulations of DDE and other organochlorines (Peakall et al. 1990). Bioaccumulation through the peregrines' prey was the suspected immediate source of these residues; however, the origin of these contaminants remained unknown. Available pesticide residue data for peregrine prey from western Canada showed that migratory insectivorous and omnivorous bird species carried elevated levels of DDE and other organochlorines. Because DDT and other organochlorines were severely restricted or completely banned, both in Canada and the United States, we assumed that the Peregrine Falcon and its prey acquired these residues on migration or on the wintering grounds.

Data on pesticide use and toxic chemical residues, either in migrant or resident prey,

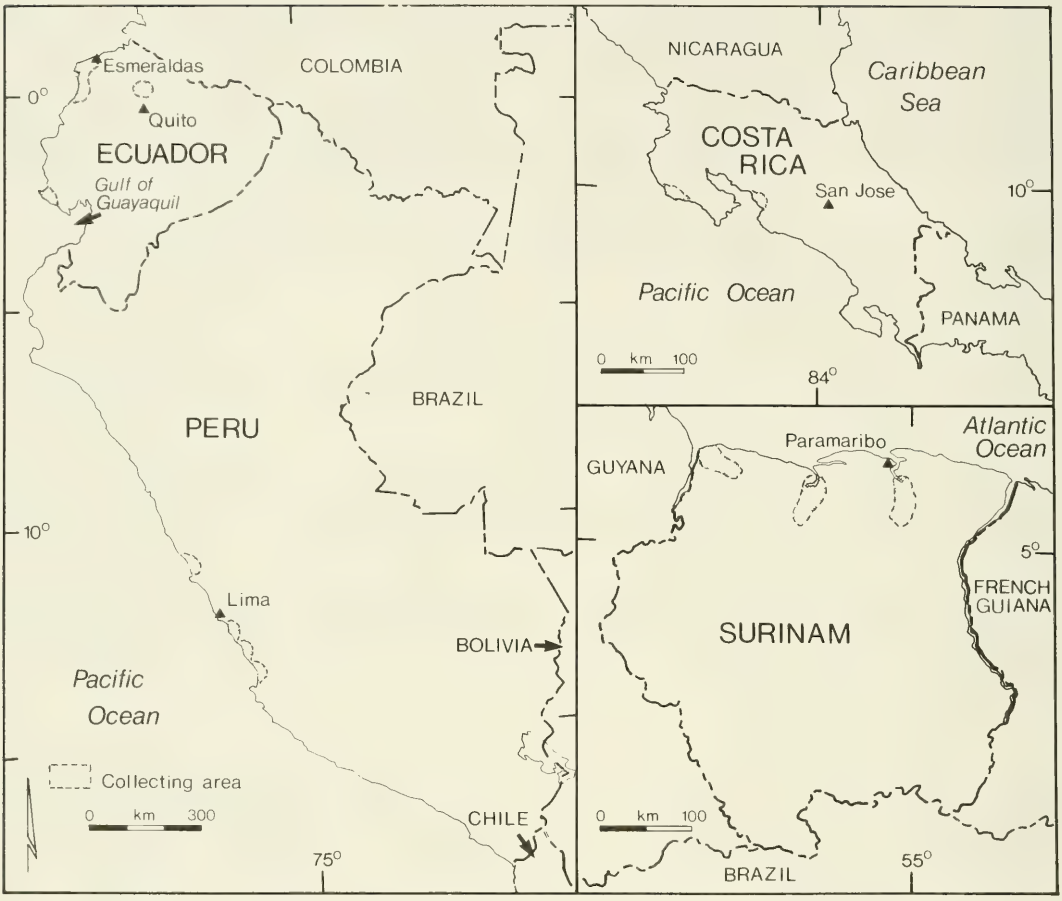

FIGURE 1. Areas in Suriname, Peru, Ecuador, and Costa Rica where collecting occurred.

remains scarce south of the United States. To determine potential sources of this contamination, we explored the feasibility of cooperative studies in different areas of Latin America. The study's primary objective was to determine residue levels in migratory prey immediately after their arrival on the wintering grounds in the fall and just before their departure north in the spring. Secondary objectives included measuring residue levels in resident prey, determining the quantity of pesticides used and their use patterns in each country, and assisting our cooperators by collecting and analyzing species of interest, e.g., shrimp and food fish.

Sampling Locations

Suriname, situated on the northeast coast of South America, uses pesticides in the rice and fruit industries and in the control of malaria mosquitoes (Suriname agriculture officials, personal communication) (Figure 1). Numerous migrant shorebirds congregate in the shallow water of the coastal mangroves and feed at low tide on the extensive coastal mud flats (Spaans 1978). Peregrine Falcons, frequent winter residents, arrive from the north with these migrants and establish winter hunting territories, many in the mangroves and in adjacent towns and cities.

Peru, the third largest nation in area in South America, has numerous rivers flowing from the Andes Mountains towards the Pacific Ocean, creating mudflats, sandy beaches, and coastal lagoons. Shorebirds feed in these areas as well as in sewage outflows near towns.

In Ecuador, salt ponds back from the coastline, coastal lagoons, and the beach serve as feeding areas for migrating shorebirds. In Costa Rica the coastal mangrove areas, mud flats formed at river estuaries, lagoons back from the ocean, salt flats, and shrimp ponds provide feeding areas for migrant shorebirds, the majority of Costa Rica's water birds. "By mid-November, most northern migrants remaining in Cost Rica are winter residents. . ." (Stiles 1983). Any northern migrants

TABLE 1. Organochlorine residues in migrant prey of Peregrine Falcons collected in Suriname during 1979 amd 1980 (breast muscle analyses in ppm wet weight).

Species	Sample Time[1]	N[2]	DDE	P,P'-DDT	PCB	HE[3]	Diel[4]	End[5]	A-BHC	B-BHC
Long-billed Dowitcher	F	3	0.01	0.00	0.07	0.02	0.02	0.00	0.00	0.00
Least Sandpiper		10	0.01	0.00	0.04	0.01	0.01	0.02	0.00	0.00
Semipalmated Sandpiper		10	0.01	0.00	0.07	0.01	0.00	0.00	0.00	0.00
		4	0.01	0.00	0.32	0.00	0.01	0.00	0.00	0.00
		10	0.02	0.00	0.06	0.00	0.00	0.00	0.00	0.00
		8	0.02	0.00	0.11	0.00	0.01	0.00	0.08	0.05
		8	0.43	0.00	0.32	0.00	0.02	0.00	0.00	0.00
Western Sandpiper		10	0.01	0.00	0.14	0.00	0.00	0.00	0.00	0.00
Lesser Yellowlegs		9	0.01	0.00	0.07	0.00	0.01	0.01	0.00	0.00
Solitary Sandpiper		9	0.01	0.00	0.07	0.00	0.00	0.00	0.00	0.00
		10	0.13	0.00	0.09	0.00	0.07	0.08	0.01	0.06
Ruddy Turnstone		6	0.05	0.00	0.17	0.00	0.00	0.00	0.00	0.00
		10	0.07	0.00	0.42	0.00	0.00	0.00	0.00	0.00
Least Sandpiper	S	6	0.01	0.01	0.03	0.03	0.01	0.00	0.00	0.00
Semipalmated Sandpiper		10	0.01	0.00	0.10	0.02	0.01	0.00	0.00	0.00
		12	0.01	0.01	0.23	0.03	0.02	0.00	0.00	0.00
		8	0.01	0.03	0.04	0.05	0.00	0.00	0.00	0.00
		10	0.01	0.00	0.07	0.04	0.01	0.00	0.00	0.00
Sanderling		1	0.03	0.00	0.22	0.05	0.00	0.00	0.00	0.00
Spotted Sandpiper		1	0.10	0.00	0.13	0.08	0.01	0.00	0.00	0.00
Semipalmated Plover		4	0.12	0.05	1.04	0.03	0.12	0.00	0.00	0.00
Ruddy Turnstone		10	0.01	0.01	0.11	0.04	0.01	0.00	0.00	0.00

[1]F = fall; S = following spring; [2]N = number of samples in each species pool, collected in separate areas; [3]HE = heptachlor epoxide; [4]Diel = dieldrin; [5]End = endrin.

present during the northern summer are non-breeders.

Methods

In cooperation with government agencies, universities, and private individuals, we collected the fall samples. During the following spring, each country's cooperators sampled the same areas for the same species, and prepared the samples for analyses using the techniques learned the previous fall.

In each country we selected, if possible, at least ten prey species that were regular winter visitors. The proposed total sample size for each migrant prey was 20, ten in the fall and ten in the spring. To get a better overall view of residues present, we generally analyzed only pools of five or more specimens.

Samples were collected by shooting and mist-netting. Because of the intense heat and numerous insects, we plucked and eviscerated the birds immediately except for the heart and liver. We stored all samples in "Ziploc" plastic bags inside coolers with ice, and later placed them into a freezer. We purchased fish, shrimp, and barnacle samples directly from fishermen or fish markets.

Later we thawed the samples, removed the beak and feet, pooled each species, and using poultry shears to cut each sample into small pieces. By grinding the samples with a hand powered meat grinder, we produced a homogenate from which we took an aliquot, after thorough mixing. Each aliquot was placed in a vial that had been cleaned with acetone. We placed aluminum foil under the plastic caps before capping them; all vials were stored in a freezer.

Frozen samples were transported by air back to Canada. Analyses of samples from Suriname and Peru were carried out at the Ontario Research Foundation (Reynolds and Cooper 1975), and those from Ecuador and Costa Rica at the National Wildlife Research Centre, Ottawa (Peakall et al. 1986).

Results

Peregrine Falcon prey representing 20 migrant species and 690 individuals were collected. Cooperating ornithologists in each country advised us that migratory shorebirds constituted the principal prey of the Peregrine Falcon on its wintering grounds; therefore shorebirds account for the majority of the samples collected.

Suriname

During November and December 1979 and again in March and April 1980, we collected at several coastal mud flats and inland in the rice growing areas (Figure 1). The organochlorine residues in these migratory shorebirds were generally low with

only four pools that equalled or exceeded 0.10 ppm DDE (Table 1). The mean DDE level calculated for the fall samples was 0.06 ppm and for the spring samples was 0.03 ppm. The only other organochlorine to show significant levels was the PCBs, with one species pool at 1.04 ppm and a mean level of 0.18 ppm.

Residue data for two resident raptors provide a different picture (Table 2), although these data represent single samples for all but the Snail Kite (*Rostrhamus sociabilis*). One kite, collected in an area recently drained between crops, indicates low residue levels. These kites fed on snails exposed in the mud or in shallow water. The other kite sample, with the elevated residue levels, originated from an area adjacent to a flooded rice field. Here spraying occurred in the morning before sampling, and the kites fed on snails from the water's surface. Snails, *Pomacea*, collected from here show higher A-BHC and B-BHC levels than the Snail Kites.

One of two Bat Falcon (*Falco rufigularis*) samples showed moderately elevated DDE and PCB levels; however, these DDE levels present no need for concern. For a raptor feeding strictly on insects and bats in open areas or in clearings near human habitation, we expected some exposure to DDT because of malaria control practises employed. In contrast, the three swallow samples, migrants from other parts of South America, show few organochlorine residues.

Resident fish, shrimp, and barnacle samples indicate low organochlorine residues. Even a Catfish (*Bagre* spp.), part of a die-off in a rice growing area, showed low residue levels. The turtle eggs showed only trace amounts of organochlorines. We also failed to detect any residue levels in excess of 0.01 ppm in the sediment and plant samples taken.

Peru

We collected 12 peregrine prey and one food species along the coast from Chiclayo in the north and south to Paracas and Lagoona Grande during October and November in 1983 and again in March and April of 1984 (Figure 1). Except for the shrimp, all samples analyzed exhibited a wide range of organochlorine and PCB levels (Table 3). The highest mean DDE level in all migrant species, 2.69 ppm, occurred here, with nine of 17 species

TABLE 2. Organochlorine residues in resident prey of Peregrine Falcons collected in Suriname during 1979 and 1980. Some species of interest to cooperators are also included (breast muscle of birds and muscle tissue of other species in ppm wet weight). Symbols as in Table 1.

Species	Sample Time	N	DDE	P,P'-DDT	PCB	HE	Diel	End	A-BHC	B-BHC
Snail Kite	F	7	0.01	0.00	0.01	0.01	0.05	0.39	0.02	0.00
		11	0.01	0.00	0.01	0.01	0.02	0.07	1.50	0.39
Bat Falcon		1	0.56	0.01	0.31	0.01	0.04	0.00	0.00	0.11
		1	2.68	0.00	2.68	0.05	0.06	0.00	0.00	0.11
Blue and White Swallow		1	0.01	0.00	0.13	0.00	0.00	0.00	0.00	0.00
		1	0.01	0.00	0.03	0.01	0.00	0.00	0.01	0.00
White-Winged Swallow		1	0.01	0.00	0.16	0.00	0.00	0.00	0.00	0.00
Barnacles		10+	0.01	0.00	0.02	0.00	0.00	0.00	0.01	0.06
Fish A & B		1	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.06
Fish Bagre Bagre		10	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Fish Bagre Bagre		10	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Fish Bangamerie		10	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Fish Catfish		10	0.01	0.00	0.02	0.00	0.00	0.04	0.06	0.00
Fish Krobia		1	0.05	0.00	0.02	0.00	0.03	0.01	0.10	0.00
Fish Kwi-Kwi		1	0.01	0.00	0.03	0.01	0.01	0.00	0.01	0.00
Fish Patalia		1	0.03	0.00	0.02	0.00	0.01	0.09	0.01	0.00
Fish Srieba		1	0.01	0.00	0.02	0.00	0.04	0.69	0.15	0.00
Shrimp		10+	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
		10+	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
		10+	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
		10+	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Snails		10+	0.01	0.00	0.01	0.00	0.01	0.01	7.94	0.88
Turtle eggs[1]	S	8	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00
		10	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
		10	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
		8	0.01	0.00	0.05	0.01	0.00	0.00	0.00	0.00
		10	0.01	0.00	0.04	0.01	0.00	0.00	0.00	0.00
		10	0.01	0.00	0.04	0.01	0.01	0.00	0.00	0.00

[1]We pooled the eggs for analyses.

TABLE 3. Organochlorine residues in migrant and resident prey of Peregrine Falcons collected in Peru during 1983 and 1984. Some species of interest to cooperators are also included (whole body analyses in ppm wet weight). Symbols as in Table 1.

Species	Sample Time	N	DDE	P,P'-DDT	PCB	HE	Diel	End	A-BHC	B-BHC
Migrants										
Franklin's Gull	F	10	0.61	0.01	0.29	0.11	0.08	0.01	0.01	0.01
Wilson's Phalarope		10	0.91	0.01	0.11	0.05	0.03	0.02	0.00	0.07
Greater Yellowlegs		11	1.90	0.01	0.15	0.01	0.05	0.02	0.00	0.01
Lesser Yellowlegs		10	5.67	0.01	0.15	0.01	0.02	0.03	0.00	0.01
Willet		10	2.57	0.01	3.12	0.02	0.03	0.00	0.00	0.01
Spotted Sandpiper		11	0.21	0.00	0.43	0.01	0.01	0.01	0.00	0.01
Barn Swallow		9	2.23	0.02	0.55	0.07	0.07	0.03	0.01	0.01
Franklin's Gull	S	10	1.38	0.01	0.76	0.03	0.09	0.04	0.02	0.04
Wilson's Phalarope		7	0.20	0.03	0.13	0.01	0.01	0.02	0.00	0.02
Least Sandpiper		43	0.01	0.00	0.03	0.01	0.01	0.00	0.00	0.01
Western Sandpiper		12	0.03	0.00	2.48	0.01	0.02	0.00	0.00	0.01
Greater Yellowlegs		10	0.20	0.00	0.30	0.00	0.01	0.00	0.00	0.01
Lesser Yellowlegs		11	0.90	0.01	0.10	0.01	0.01	0.00	0.00	0.01
Willet		10	3.08	0.01	4.23	0.01	0.06	0.02	0.01	0.01
Spotted Sandpiper		10	3.40	0.00	1.50	0.01	0.05	0.01	0.00	0.03
Semipalmated Plover		12	4.76	0.01	0.23	0.02	0.47	0.06	0.01	0.04
Barn Swallow		9	17.60	0.05	0.87	0.11	1.75	0.22	0.17	0.28
Residents										
Killdeer	F	6	8.37	0.01	0.51	0.04	0.98	0.04	0.00	0.01
	S	10	70.70	0.02	0.75	0.12	1.10	0.24	0.04	0.24
Bat	S	5	67.30	1.52	0.31	0.06	1.23	0.07	0.03	0.98
Shrimp	F	10+	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00

pools showing whole body levels in excess of 1.00 ppm. The increase in the mean DDE levels from fall to spring, from 2.01 ppm to 3.16 ppm, and in four of seven species pools, suggests continued exposure to DDE or its parent compound p,p'-DDT. The exceptionally high mean DDE level, 48.79 ppm, in the three resident species supports this conclusion. The presence of 1.52 ppm of p,p'-DDT in bats indicates the continued use of DDT for pest control in the Lima area.

Migrant birds collected in the fall showed no evidence of elevated levels of dieldrin, A-HCH or B-HCH; however, spring collections of migrant Barn Swallows (*Hirundo rustica*) and Semipalmated Plovers (*Charadrius semipalmatus*) and the resident bats and Killdeer (*Charadrius vociferous*) show high dieldrin levels. Some evidence of both A-BHC and B-BHC exposure was found in bats, Killdeer, and swallows. These data suggest continued use and current exposure of these birds to dieldrin and B-BHC.

Ecuador

Sampling occurred in November 1983 and in February 1984 between Esmeraldes and Salinas (Figure 1). With the exception of DDE and PCB, most organochlorine compounds were present at low levels (Table 4). The mean DDE level for migrant peregrine prey increased from 1.16 ppm in the fall to 1.49 ppm in the spring, and ten (62%) of the 16 species pools exceeded 1.00 ppm. Elevated DDE levels in 10 of 16 samples, and the increased levels from fall to spring in three of four species pools, suggest that migrants over-wintering in Ecuador still encounter DDE. DDT use in malaria campaigns continues, but few data on quantities used are available (e.g., 1200 tons imported in 1987).

Moderate PCB residue levels occurred in all samples as did trace levels of dieldrin, heptachlor epoxide, and B-BHC. These data indicate continued use of the parent chemicals aldrin, dieldrin, chlordane, BHC or their metabolites. The lone resident species sampled, the Band-tailed Seedeater (*Sporophila analis*), a granivorous species, showed low organochlorine residue levels as expected (Risebrough, Davis, and Anderson 1970).

Costa Rica

We collected samples in November 1984 and in March of 1985 near Colorado, Puntarenas, and Canjas (Figure 1). The 19 species pools of migrants show the second lowest mean DDE level in this study for fall samples, 0.81 ppm, and for spring samples, 0.40 ppm (Table 5). Four of the species pools exceed the 1.00 ppm level for whole body

TABLE 4. Organochlorine residues in migrant and resident prey of Peregrine Falcons collected in Ecuador during 1983 and 1984. Some species of interest to cooperators are also included (whole body analyses in ppm wet weight). Symbols as in Table 1.

Species	Sample Time	N	DDE	P,P'-DDT	PCB	HE	Diel	End	A-BHC	B-BHC
Migrants										
Franklin's Gull	F	12	0.57	0.03	0.46	0.14	0.17	0.07	0.01	0.01
Long-billed Dowitcher		5	0.36	0.00	0.33	0.01	0.01	0.01	0.00	0.01
Semipalmated Sandpiper		10	0.08	0.02	0.33	0.01	0.04	0.01	0.00	0.01
Western Sandpiper		10	1.83	0.03	0.27	0.00	0.09	0.02	0.00	0.01
Lesser Yellowlegs		3	1.27	0.01	0.11	0.01	0.01	0.01	0.00	0.01
Willet		9	0.57	0.01	0.21	0.01	0.01	0.00	0.00	0.01
Spotted Sandpiper		10	0.50	0.01	0.20	0.01	0.02	0.00	0.00	0.01
Semipalmated Plover		10	3.75	0.01	0.16	0.01	0.11	0.02	0.00	0.01
Barn Swallow		10	1.49	0.02	0.21	0.03	0.03	0.03	0.01	0.02
Franklin's Gull	S	10	2.61	0.04	2.44	0.02	0.08	0.00	0.00	0.01
Long-billed Dowitcher		10	1.26	0.00	0.16	0.03	0.03	0.00	0.00	0.03
Stilt Sandpiper		4	1.40	0.00	0.20	0.01	0.02	0.00	0.00	0.01
Sanderling		10	1.37	0.00	0.46	0.00	0.01	0.00	0.00	0.00
Greater Yellowlegs		9	1.85	0.00	0.07	0.01	0.01	0.00	0.00	0.01
Lesser Yellowlegs		10	1.44	0.00	0.09	0.02	0.01	0.00	0.00	0.01
Semipalmated Plover		9	0.53	0.00	0.17	0.01	0.02	0.00	0.00	0.02
Resident										
Band-tailed Seedeater	S	10	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00

TABLE 5. Organochlorine residues in migrant and resident prey of Peregrine Falcons collected in Costa Rica during 1984 and 1985. Some species of interest to the cooperators are also included (whole body analyses in ppm wet weight). Symbols as in Table 1.

Species	Sample Time	N	DDE	P,P'-DDT	PCB	HE	Diel	End	A-BHC	B-BHC
Migrants										
Common Snipe	F	10	0.68	0.06	0.06	0.17	0.79	0.00	0.00	0.00
Short-billed Dowitcher		10	0.13	0.00	0.09	0.01	0.03	0.00	0.00	0.00
Least Sandpiper		10	0.06	0.00	0.02	0.01	0.01	0.00	0.00	0.00
Western Sandpiper		10	0.08	0.02	0.24	0.02	0.07	0.00	0.00	0.00
Marbled Godwit		3	0.25	0.00	0.15	0.01	0.01	0.00	0.00	0.00
Lesser Yellowlegs		8	1.09	0.00	0.14	0.38	0.02	0.00	0.00	0.01
Willet		10	1.84	0.00	0.08	0.03	0.01	0.00	0.00	0.00
Spotted Sandpiper		10	0.24	0.00	0.05	0.03	0.15	0.00	0.00	0.00
Semipalmated Plover		4	0.33	0.00	0.23	0.00	0.01	0.00	0.00	0.00
Barn Swallow		10	3.35	0.12	0.16	0.16	0.15	0.00	0.01	0.05
Least Sandpiper	S	10	0.05	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Semipalmated Sandpiper		10	0.09	0.00	0.22	0.01	0.02	0.00	0.00	0.00
Western Sandpiper		10	0.03	0.00	0.03	0.00	0.01	0.00	0.00	0.00
Lesser Yellowlegs		10	0.53	0.00	0.06	0.01	0.06	0.00	0.00	0.01
Willet		10	0.45	0.00	0.07	0.01	0.04	0.00	0.00	0.00
Spotted Sandpiper		10	0.30	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Long-billed Curlew		10	1.20	0.00	0.04	0.00	0.01	0.00	0.00	0.00
Semipalmated Plover		10	0.19	0.00	0.06	0.01	0.05	0.00	0.00	0.00
Barn Swallow		10	0.79	0.01	0.12	0.08	0.01	0.00	0.00	0.00
Residents										
Black Crowned Night Heron[1]	F	10	4.59	0.13	0.16	0.04	0.02	0.00	0.00	0.00
Cattle Egret[1]	S	10	0.37	0.02	0.00	0.18	0.01	0.00	0.00	0.00
Fish Corvina		–	0.02	0.00	0.06	0.00	0.01	0.00	0.00	0.00
Shrimp		10+	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1]Eggs from each species pooled.

analyses, although three are fall samples, suggesting that they arrived with these residues already in their tissues. In six of seven migrant species collected, both in the fall and the spring, DDE levels declined. Except for the high DDE levels in the Black-crowned Night-heron (*Nycticorax nycticorax*) eggs, the other organochlorine residues were low.

Discussion

The higher DDE, A-BHC, and B-BHC residue levels in carnivorous and insectivorous species, i.e., bats from Peru with 67.30 ppm DDE and Barn Swallows from Peru, Ecuador and Costa Rica with DDE ranging from 0.79 to 17.60 ppm, highlight the link between feeding habits and residue levels. Omnivorous and granivorous species generally exhibited lower DDE levels. Resident species usually expressed higher DDE levels than migrants, i.e., Killdeer in Peru with 8.37 ppm in the fall and 70.70 ppm in the spring versus Spotted Sandpipers (*Actitis macularia*) with 0.21 ppm in the fall and 3.40 ppm in the spring.

In Suriname the migrant species, all omnivorous, showed the lowest mean DDE levels, both in the fall and the spring, and the resident species the second lowest DDE levels. During 1979-1981 DDT accounted for only a small portion of the pesticide market here whereas BHC and aldrin dominated (FAO 1980), as shown by the A-BHC and B-BHC data from the snails and Snail Kites. The two South American migrant swallows showed low DDE levels but slightly elevated PCB levels.

Fifty-eight percent of the migrant species collected in Peru and Ecuador, all omnivores except the Barn Swallow, contained DDE whole body levels in excess of 1.00 ppm wet weight. In Peru, the mean DDE residue level for fall samples, 2.01 ppm, increased to 3.16 in the spring; and in Ecuador, the mean DDE residue level for fall samples, 1.16 ppm, increased to 1.49 in the spring. Seven of eleven migrant species, sampled both in the fall and the spring, showed increased DDE levels. Quantities of DDT used in Peru during 1978 surpassed all other organochlorines, followed by BHC and aldrin; Maltby (1980) predicted increased use of these three compounds by 1988. During 1978 in Ecuador, aldrin, endosulfan, and endrin appeared as the only organochlorines used (Maltby 1980). Again by 1990 the overall use of insecticides is expected to increase (Frost and Sullivan 1981).

The omnivorous migrants sampled in Costa Rica indicate that minimal or no DDT use exists there. The mean DDE residue levels in fall and spring samples decreased from 0.81 ppm to 0.40 ppm. Even the DDE levels in Barn Swallows declined significantly over winter. The elevated DDE residue levels in the resident Black-crowned Night-heron eggs clash with other Costa Rican samples; however, these herons may frequent areas of residual contamination, since DDE persists for some time even after use ceased. Or they fed in areas of present day use of DDE, as yet undetected.

As expected, the lone granivorous species sampled in Ecuador contained the lowest organochlorine levels. All fish, shrimp, barnacles, turtle eggs, and sediment samples showed little or no residues.

Conclusions

Peregrine Falcons migrating or wintering in Suriname or Costa Rica escape significant contamination by DDE or other organochlorines; however, in Peru and Ecuador exposure continues. These residue levels suggest continued adverse effects on the reproductive success of Peregrine Falcons wintering there. Because qualitative and quantitative use of pesticides in each country remain difficult to obtain, future samples should contain a greater proportion of resident species, more specifically insectivorous and carnivorous species. Such data would indicate better the nature of pesticide use in each country and identify hot spots that may be of concern. Identifying where peregrine populations overwinter and correlating these data with pesticide use patterns remains another challenge.

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Notes

Isohypsibius woodsae, a New Species of Eutardigrada (Tardigrada) from British Columbia

R. D. KATHMAN

Department of Biology, University of Victoria, Victoria, British Columbia
Present address: 4256 Warren Road, Franklin, Tennessee 37064

Kathman, R. D. 1990. *Isohypsibius woodsae*, a new species of Eutardigrada (Tardigrada) from British Columbia. Canadian Field-Naturalist 104(2): 293–294.

A new species of eutardigrade was found during a study of the tardigrades of Vancouver Island, British Columbia. *Isohypsibius woodsae* n. sp. differs from other species in the genus by the number and arrangement of dorsal gibbosities, reticulated pattern of the cuticle, buccopharyngeal apparatus and claw characters.

Key words: Tardigrada, *Isohypsibius woodsae* n. sp., British Columbia.

A survey of tardigrades of five mountains on Vancouver Island, B.C., was conducted during 1986 and 1987. Although the primary purpose was to study the relationship of tardigrade species to moss species, and to altitude, a new species of *Isohypsibius* was discovered in the course of the work. Prior to this survey, a total of only 18 species of tardigrades had been reported from British Columbia, by Richters (1908) and Murray (1910). In this paper *Isohypsibius woodsae*, new species, is described from Mt. Arrowsmith. Two other new species from the Vancouver Island area are described elsewhere (Kathman and Nelson 1989; Kathman, *in press*).

Materials and methods

The specimens of *Isohypsibius woodsae* were collected in the moss *Dicranum fuscescens* Turn. at 1057 m on Mt. Arrowsmith, 10 July 1987.

Samples of moss were placed in paper bags and air-dried for several months. Each sample was then removed from the bag, placed in a stoppered funnel and allowed to soak in water for eight hours, after which the moss was removed and shaken in a separate container of water several times. The water and its contents were poured through a 45 μm mesh sieve to retain the tardigrades, which were placed in a gridded petri dish and extracted using a stereomicroscope. Each tardigrade was placed in Hoyer's mounting medium on a microscope slide and sealed with a cover slip. After complete drying of the mountant the cover slip was ringed with nail polish to prevent further air penetratrion.

Identifications were made using a phase-contrast compound microscope with oil immersion. All measurements were made using a calibrated eyepiece micrometer. All drawings were done with a drawing tube attached to the compound microscope.

Taxonomic Account

Eutardigrada Marcus, 1927
Hypsibiidae Pilato, 1969
Isohypsibius Thulin, 1928
***Isohypsibius woodsae* n. sp.**
(Figure 1)

Description. Holotype. Length 392 μm, eyespots present. Cuticle reticulated with fairly wide-spaced polygons; 10 rows of gibbosities, with four in each row except row 10, which has two. Thin buccopharyngeal tube, length 39 μm, width 3.7 μm. Pharyngeal bulb round, with large apophyses and two rod-shaped macroplaccoids; first macroplacoid 3 μm long slightly constricted in the middle, second macroplacoid 2 μm long; microplacoids absent. Claw sequence 2121; doubleclaws on each leg of different size; with two accessory points on the primary branch; lunules present on claws on all legs but most obvious on those of leg IV; small sclerotized bar present near the internal claw on legs I-III. USNM #235445.

Paratype. Total length 310 μm; buccopharyngeal tube 37.5 μm long, 2.5 μm wide; remainder of description the same as the holotype. 1 specimen, Kathman collection.

Type locality. Northwest aspect of Mt. Arrowsmith at 1057 m, Vancouver Island, British Columbia, Canada.

Etymology. Named for Roberta Woods, who helped collect these and many other specimens of tardigrades.

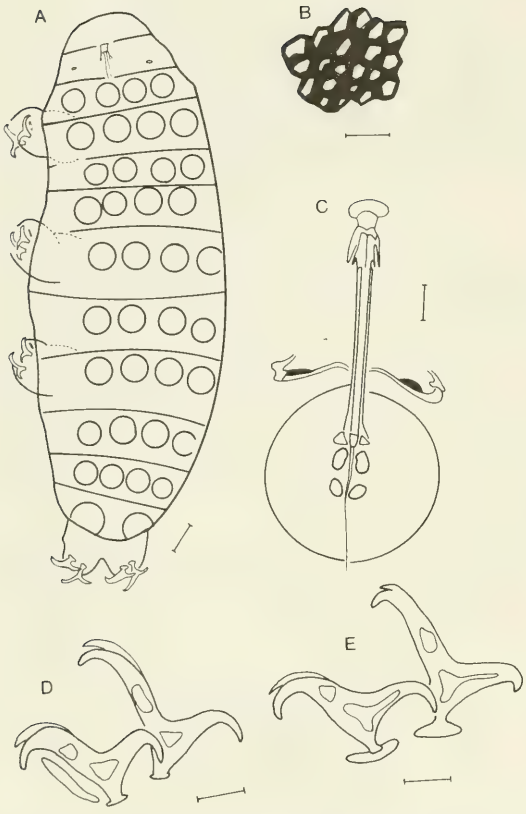

FIGURE 1. *Isohypsibius woodsae*. A, Entire animal, dorsal view; B, Reticulated pattern of cuticle, covering entire dorsal surface; C, Buccopharyngeal apparatus; D, Claws of leg III; E, Claws of leg IV. Scale bars in μm as follows: A, 20; B, 4.8; C, 6; D, 4.8; E, 6.

Discussion. Approximately half of the nearly 100 species in the genus *Isohypsibius* have gibbosities and a sculptured cuticular pattern. However, only five species have a similar number of rows of gibbosities as *Isohypsibius woodsae* with an even number of gibbosities in each of these rows and a reticulated (versus granulated or smooth) cuticle. *Isohypsibius josephi* (Iharos, 1964) has a maximum size of 300 μm, nine rows of gibbosities, a short wide buccopharyngeal tube, and a long sinuous sclerotized bar in all four pairs of legs. *Isohypsibius neoundulatus* (Durante Pasa and Maucci, 1975) is small (< 220 μm), has 18-24 transverse rows but with gibbosities in only the dorsolateral positions on six rows, has doubleclaws of equal size, and no sclerotized bars on the claws. *Isohypsibius pratensis* (Iharos, 1964) has nine rows of gibbosities with two in rows 1 and 6, four in rows 2, 4, 5, 8 and 9, and six in rows 3 and 7; the cuticle is finely granulated as well as reticulated; and, presumably, there are no bars on the claws although this is not specifically mentioned. *Isohypsibius rudescui* (Iharos, 1966) is < 225 μm long, has 10 rows of gibbosities with two in rows 1, 2, 4 and 10, and four in rows 3, 5, 6, 7, 8 and 9, with some gibbosities noticably larger than others, and presumably has no bars on the claws. *Isohypsibius woodsae* exhibits several characters which distinguish it from the only other species which has 10 rows of four gibbosities in each row except the tenth which has two. *Isohypsibius bartosi* (Iharos, 1966) is a smaller animal (240-270 μm) than *I. woodsae* (310 and 292 μm), eyespots are absent and the cuticle is finely granulated in *I. bartosi*. Although the description of *I. bartosi* states that the doubleclaws are of different length, the illustration (Iharos, 1966; in Ramazzotti and Maucci, 1983) indicated that this difference is minimal, whereas in *I. woodsae* there is a distinct difference between the external and internal claws. There is a distinct sclerotized bar near the internal claw of the first three pairs of legs and lunules are present on the claws of all legs in *I. woodsae*. The description of *I. bartosi* mentions neither of these characters.

Acknowledgments

I wish to thank H. Dastych for examining *I. woodsae*, R. Woods for help with the collections, and W. Schofield for verification of the moss. This project was partially funded by British Columbia Science Council's Graduate Research Engineering and Technology Award to Dr. Richard Ring.

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Advancement of Goose Nesting Dates in the Hudson Bay Region, 1951-1986

CHARLES D. MACINNES[1], ERICA H. DUNN[1,2], DONALD H. RUSCH[3], FRED COOKE[4], and F. GRAHAM COOCH[5]

[1]Ministry of Natural Resources, Wildlife Research Section, P.O. Box 5000, Maple, Ontario L6A 1S9
[2]Current address: Cornell Laboratory of Ornithology, 159 Sapsucker Woods Road, Ithaca, New York 14850
[3]Department of Wildlife Ecology, University of Wisconsin, Madison, Wisconsin 53706
[4]Department of Biology, Queen's University, Kingston, Ontario K7L 3N6
[5]Canadian Wildlife Service, Ottawa, Ontario K1A 0E7

MacInnes, Charles D., Erica H. Dunn, Donald H. Rusch, Fred Cooke and F. Graham Cooch. 1990. Advancement of goose nesting dates in the Hudson Bay region, 1951-1986. Canadian Field-Naturalist 104(2): 295-297.

Nest initiation and hatch dates of Snow Geese (*Chen caerulescens*) and two races of Canada Geese (*Branta canadensis*) nesting in Hudson Bay became progressively earlier in the period 1951-1986. Snow Geese might have been adjusting to the milder climate of recently-colonized breeding areas in southern and western parts of the bay, but because other species showed the same trend of nesting dates, we suggest instead that the cause was climatic amelioration.

Key Words: Snow Gooose, *Chen caerulescens*, Canada Goose, *Branta canadensis*, Hudson Bay, laying date, hatch date.

Snow Goose (*Chen c. caerulescens*) populations have increased in the Hudson Bay region over the last several decades (Kerbes 1975; Boyd et al. 1982). At the same time, annual nesting dates of Snow Geese seem to have become earlier. Date of nesting is correlated both to general and annual weather conditions (Cooch 1961; Cooke et al. 1980), so the trend to earlier dates might merely reflect general climatic amelioration. However, colonies in west and south Hudson Bay are thought to have been founded by birds from farther north (Hanson et al. 1972), and it has been proposed that earlier nesting dates in Snow Geese might represent a gradual adjustment to the milder climatic conditions at the new nesting sites. We can test this hypothesis by examining nesting dates of other goose species that nest in Hudson Bay, since all species should be equally affected by climate change, while only Snow Geese should be adjusting to new nesting areas.

In this note, we compare Lesser Snow Goose nesting dates and clutch size (which depends on nesting date), to those for small and medium-sized Canada Goose (*Branta canadensis hutchinsii-parvipes* complex and *B. c. interior*, respectively).

Methods

We analyzed data from five localities with information for five or more years for at least one index of breeding season timing. Locations were McConnell River (60°50′N, 94°25′W; Snow Goose and small Canada Goose), La Perouse Bay (58°24′N, 94°24′W; Snow Goose), Cape Churchill (58°25′N, 93°W; medium Canada Goose), and Southampton Island (63°60′N, 86°W; Snow Goose). Indices of breeding season were date of first egg (first egg to be found at a colony) and mean date of hatch.

Date of first egg and hatch date were numbered from 25 May =1, while years were numbered from 1951=51. Regressions for nesting dates on year for each species at each site indicated straight-line relationships, so second-order variables were dropped from further analyses. To examine change of nesting dates and clutch size with year, backward step-wise multiple regressions were performed, using dummy variables for each site-species combination except for McConnell River Snow Geese, and including dummy variables for interaction of species-site variables with year. The latter were available first for removal from the regression, followed by the species-site variables.

The same procedure (with inclusion of dummy variables for site-species combinations) was used to examine the relationship of clutch size to nesting dates.

Results

When available from the same site, date of first egg and mean date of hatch were highly correlated (for McConnell River Canada Goose, $r = 0.93$, $N = 10$; McConnell River Snow Goose, $r = 0.99$, $N = 9$; La Perouse Bay Snow Goose, $r = 0.94$, $N = 19$; and for Southampton Island Snow Goose, $r = 0.93$, $N = 9$. In all cases, $P < 0.001$). This indicates that either index of nesting date was sufficient to characterize relative timing of breeding seasons among years.

Both date of first egg and mean hatch date became significantly earlier during the period 1951-1986 (Table 1). Fluctuations were usually reflected at all sites in all species (Figure 1), and there were no significant differences in the slopes of trends among sites or species.

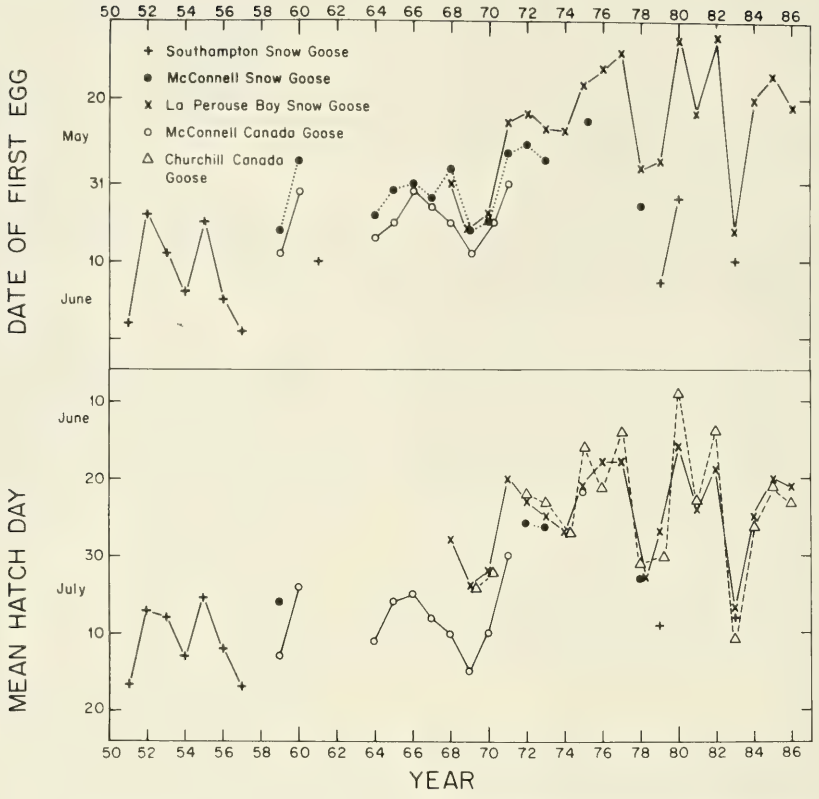

FIGURE 1. Timing of breeding in Snow and Canada geese nesting at five locations near Hudson Bay.

Clutch size was larger the earlier the date of nesting within a given year, but declined over the entire period 1951-1986 (Table 1, Figure 2).

Discussion

The high correlations among breeding season dates for the various species and races of geese

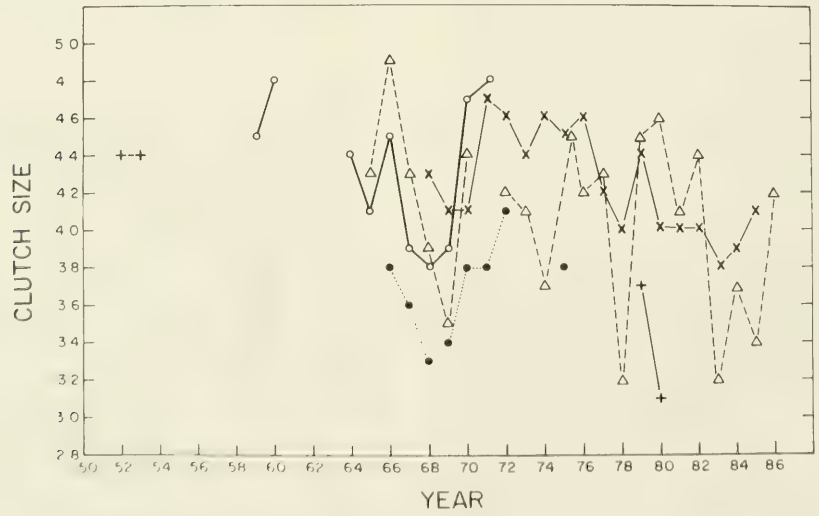

FIGURE 2. Clutch size of Snow and Canada geese nesting at Hudson Bay.

TABLE 1. Relationship of nesting dates and clutch size to year in geese nesting in Hudson Bay[1].

Regression equation	r^2	Significance
Date first egg = 20.55 –0.22 (YEAR) +10.67(S-SG) +5.22(M-CG)	0.47	< 0.05
Date mean hatch = 61.55 –0.26 (YEAR) –10.16(C-CG) –9.70(L-SG)	0.49	< 0.001
Mean clutch size = 5.51 –0.02 (YEAR) +0.43(M-CG) +0.37(L-SG) –0.02(DATE 1ST EGG)	0.30	< 0.001
Mean clutch size = 7.35 –0.03 (YEAR) –0.23(C-CG) –0.03(DATE MEAN HATCH)	0.35	<0.001

[1]C-CG = Cape Churchill, medium-sized Canada Goose; M-CG = McConnell River, small Canada Goose; L-SG = La Perouse Bay, Snow Goose; S-SG = Southampton Island, Snow Goose. No dummy variable was entered for McConnell River Snow Goose.

nesting at different localities in Hudson Bay do not support the idea that Snow Geese are gradually adjusting to the milder climate and longer nesting season of southerly breeding areas. Because Canada Geese followed the same trend, we suggest instead that the move to earlier nesting in Snow Geese is a result of regional climatic amelioration. Boyd (1982) examined broad trends in arctic spring and summer weather from 1955-1980, and showed that 1964-1970 was a period of particularly low temperatures. In the 1970s, temperatures returned to long-term averages. Much of our data for advancement of breeding season came from the 1970s; just when arctic temperatures were changing from below normal to average. Boyd's (1982) figures suggest that the warming trend of the 1970s was transient, and we expect that breeding season advancement for geese nesting in the Hudson Bay region will also prove temporary.

Clutch size in geese is usually larger in years with early nesting dates (MacInnes and Dunn 1988), as we confirmed in this analysis. However, clutch size of geese nesting in Hudson Bay decreased overall in the period 1951-1986, even though average nesting dates became earlier (this paper; Cooch et al. 1989). This paradox comes about because annual fluctuations in nesting date (and associated clutch size) are very large in comparison to the change in nest dates and clutch size taken over the entire 36-year period (Figure 2). The long-term decline in clutch size was not confined to Snow Geese (Cooch et al. 1989), but occurred to an equal extent in two races of Canada Geese (Table 1). This decline may be related to deterioration of habitat as Hudson Bay goose populations have expanded (Kerbes 1975; Cooch et al. 1989), but this question needs further investigation.

Acknowledgments

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Seed Dispersal via Amphibian Vectors: Passive Transport of Bur-marigold, *Bidens cernua*, Achenes by Migrating Salamanders, Genus *Ambystoma*

LESLIE A. LOWCOCK and ROBERT W. MURPHY

Department of Zoology, University of Toronto, and Department of Ichthyology and Herpetology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

Lowcock, Leslie A., and Robert W. Murphy. 1990. Seed dispersal via amphibian vectors: passive transport of Bur-marigold, *Bidens cernua*, achenes by migrating salamanders, genus *Ambystoma*. Canadian Field-Naturalist 104(2): 298–300.

Salamanders of the genus *Ambystoma*, known to transport molluscs (e.g. the Pea Clam, *Pisidium adamsi*) during spring migrations, were found also to be active in the dispersal of a plant (the Bur-marigold, *Bidens cernua*). Because of the circumstances, the contribution made by terrestrial amphibians to the dispersal of this species may be significant.

Key Words: Bur-marigold, *Bidens cernua*, Pea Clam, *Pisidium adamsi*, Blue-spotted Salamander, *Ambystoma laterale-jefferonianum* complex, Yellow-spotted Salamander, *Ambystoma maculatum*, breeding migration, plant dispersal.

Passive dispersal of one organism by another is a well-known common phenomenon. Among the most familiar examples are seed dispersals through feacal deposits of birds and mammals; seed pods, fruits and seeds that cling to the fur of passing mammals; mollusc and crustacean larvae parasitic on fish; and aquatic organisms such as leeches which make overland journeys on amphibious vertebrates (e.g., turtles, frogs, muskrats).

The role played by terrestrial amphibians in the distribution of other organisms is largely unknown. Rees (1952) has commented on the transport of various bivalves by different species of amphibians in Great Britain. Davis and Gilhen (1982) observed migrating Blue-spotted salamanders (*Ambystoma laterale*) in Nova Scotia transporting Pea Clams (*Pisidium adamsi*), members of a mollusc group which are also dispersed aerially by birds and insects (Mackie 1979). Herein, we describe the transportation of Pea Clams as well as seeds of the Bur-marigold, *Bidens cernua*, by both Blue-spotted (*Ambystoma laterale-jeffersonianum* complex) and Yellow-spotted salamanders (*A. maculatum*) during breeding migrations in central Ontario.

During April 1988, we conducted a study of the breeding movements of a number of species of amphibians into a large beaver pond near the south shore of Kashagawigamog Lake, Dysart Twp., Haliburton Co., Ontario (45° 00′ N, 78° 35′ W, elevation 340 m). The pond, which has two levels of relatively equal size separated and contained by beaver dams, is situated on the Precambrian shield in hilly country, lies at the top of a watershed, and covers several hectares. The upper section is of greater age as is evidenced by the extent of marshy habitat, eutrophication, and plant succession on the dam separating it from the lower level. The dam containing the lower ponding is of more recent origin. The surrounding forest is mixed second growth dominated by birch, maple, spruce and fir. Several swamps of Black Spruce (*Picea mariana*) and Northern White-cedar (*Thuja occidentalis*) exist within a 1-kim radius of the pond.

Our investigations involved the inventory of immigrating amphibians by use of a drift fence. We erected a 200-meter fence around a section of the lower aspect of the pond near its outlet. The barrier consisted of 30-cm-high black construction plastic with the lower edge buried approximately 5 cm in the soil and affixed by staples to supports (1 × 2 construction stakes or natural objects). Plastic buckets of 15 cm depth were countersunk at

TABLE 1. Comparison of numbers of Pea Clams (*Pisidium adamsi*) and achenes from Bur-marigolds (*Bidens cernua*) transported by various amphibians. N = number observed.

Taxon	N	*P. adamsi*	*B. cernua*
Ambystoma maculatum	500	6	8
A. laterale-jeffersonianum complex*	799	4	12
Notophthalmus viridescens	54	0	0
Rana sylvatica	78	1	0
Hyla crucifer	12	0	0

*At this pond, the complex consists of male and female *A. laterale* and all-female, triploid, tetraploid and pentaploid interspecific hybrids between *A. laterale* and *A. jeffersonianum*.

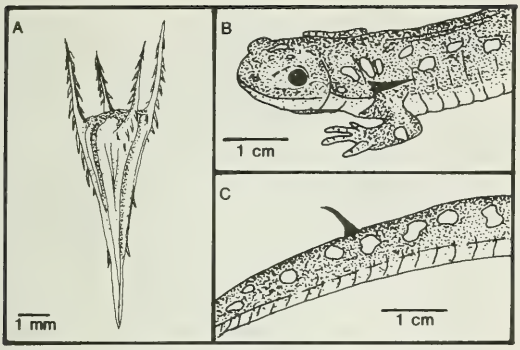

FIGURE 1. Aspects of achene of Bur-marigold, *Bidens cernua*, showing positioning of barbed awns (A), and integumental attachment to the gular region (B) and tail (C) of a Yellow-spotted salamander, *Ambystoma maculatum*.

irregular intervals as dictated by terrain and subsurface structures. The area covered by the fence represented approximately 1/50th of the total shoreline circumference. Breeding migrations began on the evening of 3 April and continued until 30 April at intervals which coincided with extensive precipitation (rain or wet snow) and favorable temperatures. Buckets were checked daily, species, numbers and sex recorded, blood samples taken (*A. laterale-jeffersonianum* complex individuals only) and then all animals were released on the pond side of the fence.

During this survey, we encountered several salamanders (genus *Ambystoma*) and a single Wood Frog (*Rana sylvatica*) which carried Pea Clams attached to the digits of their feet, as was reported previously under similar circumstances in Nova Scotia (Davis and Gilhen 1982), and encountered elsewhere (New Brunswick, Quebec and Ontario; personal observation). In addition to this phenomenon, we also recorded numerous instances in which salamanders bore a flat, pointed brown seed. Table 1 summarizes these observations. Data for the two frog species are unreliable as these animals can readily escape from buckets.

The seeds were firmly attached to the integument, typically on or near the head and occasionally on the tail (Figure 1). Attachment was by means of four barbed awns which projected longitudinally from the expanded end of a flattened elongate tetrahedral (Figure 1). The seeds were removed and later identified as the fruit or "achenes" of the Bur-marigold, *Bidens cernua* (Compositae), a plant common in wet habitats in northeastern North America (Montgomery 1977; Peterson and McKenny 1968).

Because salamanders arrived at the pond bearing both Pea Clams and Bur-marigold achenes, and were captured in buckets situated in areas away from the pond margins in which *B. cernua* grows, this is taken as evidence of dispersal by this plant. Migrating salamanders must have passed through wet habitats unsuitable for breeding en route to the pond. It is assumed that these were either swamps or seepages. Red-spotted Newts, *Notophthalmus viridescens*, represented in our sample by local land-stage juveniles returning to the pond to metamorphose into aquatic adults, would not likely have traversed wet habitats, and did not have either Pea Clams or Bur-marigold achenes on their bodies. Fate of the achenes once salamanders entered the pond is unknown, but it is assumed that they would become dislodged primarily by rough physical contact with rocks, logs or aquatic vegetation and possibly by swelling of the seed coat. Germination could be effected later in the season as springtime water levels subsided and formerly submerged pond margins were exposed. Indeed, surveys of the emergent shoreline in October revealed that in the lower pond, *B. cernua* grows only in areas that are submerged in the spring.

The overall significance of salamanders as vectors of dispersal for *B. cernua* cannot be evaluated without comparable information from mammal species, which would be expected to be the primary vectors. Bur-marigolds bloom from July-October at a height of 0.3-1.0 meters and the flowers droop with age. It is obvious from their presentation and conformation that the seeds have co-evolved to be dipersed by animals. Thus, autumn activity in the vicinity of ponds by mammals such as deer, carnivores and especially Beavers (*Castor canadensis*) and other medium-sized rodents, would seem to provide the highest probability of encounter. In spring, after snow has forced the flower heads closer to the ground, smaller rodents, insectivores and amphibians may also contribute. Because amphibians move directly, and in comparatively large numbers, from one aquatic situation to another during breeding migrations, they may contribute significantly to the dispersal totals at that time of year: A simple and rough calculation involving the totals from Table 1 shows that 20 achenes were transported between 1299 salamanders, or 1 for every 65 individuals. Since 1299 salamanders entered the pond over 1/50th of the circumference, and making the not unreasonable assumption of equal numbers approaching from all sides, around 65 000 entered over the entire pond (this may be a conservative estimate since it does not account for individuals which escaped from crowded buckets, or around the open ends of the fence). Thus, given equal probabilities of encountering drooping *B. cernua* heads during migration from all directions (although this is unlikely), approximately 1 000

seeds could have been transported to this pond alone in 1988.

How these numbers would compare with estimates for other vectors is unknown. However, it seems likely that a high percentage of achenes carried by amphibians would be deposited in areas favorable for germination, increasing the likelihood of successful dispersal.

Acknowledgments

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Foods of Black Ducks, *Anas rubripes*, Wintering in Marine Habitats of Maine

D. G. JORDE,[1,2] and R. B. OWEN, JR.[1]

[1]240 Nutting Hall, University of Maine, Orono, Maine 04469
[2]Present address: U.S. Fish and Wildlife Service, Patuxent Wildlife Research Centre, Laurel, Maryland 20708

Jorde, D. G., and R. B. Owen, Jr. 1990. Foods of Black Ducks, *Anas rubripes*, wintering in marine habitats of Maine. Canadian Field-Naturalist 104(2): 300–302.

Diet and foraging habitats of Black Ducks (*Anas rubripes*) wintering along the central coast of Maine were studied during 1983 and 1984. Marine invertebrates accounted for 96% of the diet. Amphipods (*Gammarus oceanicus*), periwinkles (*Littorina* spp.), and Blue Mussels (*Mytilus edulis*) were the principal foods eaten.

Key Words: Black Duck, *Anas rubripes*, food habits, invertebrates, Maine, winter.

Black Ducks (*Anas rubripes*) and other waterfowl have the ability to change foraging behavior and adapt to a wide range of diets within and among seasons and geographic areas (Jorde and Owen 1988a). For example, the diet of Black Ducks wintering in coastal habitats is mostly animal matter (Hartman 1963; Grandy 1972a, 1972b) whereas their diet at inland wintering sites is predominantly plant matter (Winner 1959; Reed 1971). Diets may differ among local wintering areas because of habitat diversity, nutritional value of foods, and different foraging patterns. The composition and nutritional value of different diets can affect lipid reserves (Perry et al. 1986), efficiency of digestion and true metabolizable energy (Jorde and Owen 1988a), and the ability of individuals to withstand periods of cold weather (Baldassarre et al. 1986). Knowledge of waterfowl diets at specific wintering areas is needed to modify habitat suitability models and improve habitat management of waterfowl.

The objective of this study was to compare previous studies with the current diet and foraging habitats of Black Ducks wintering along the central coast of Maine.

Study Area and Methods

Food samples were obtained from Black Ducks in the mid-coastal region of Maine at Mt. Desert Narrows/Jordan River (MN/JR) and Raccoon Cove/Skillings River (RC/SR) during January, February, and March of 1983 and 1984. Ducks were collected with a shotgun, without using decoys, during daylight hours at three principal habitats used for foraging: rockweed ledges, mud flats, and Blue Mussel beds. Birds were observed

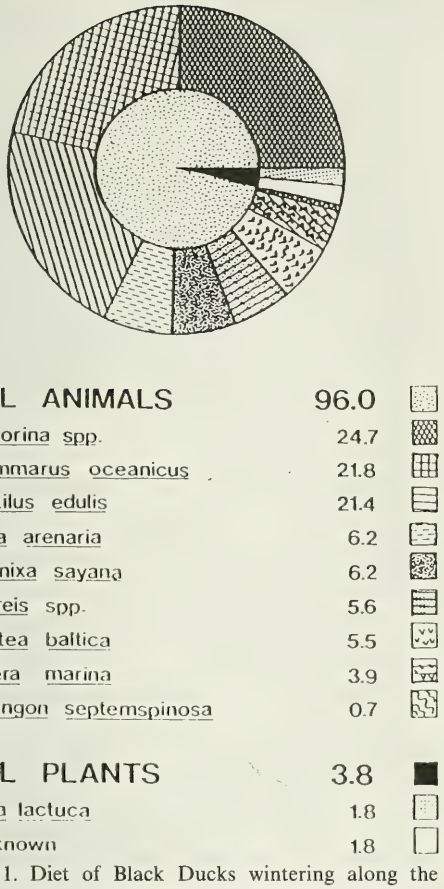

FIGURE 1. Diet of Black Ducks wintering along the central coast of Maine during 1983 and 1984. Data are expressed as aggregate percent dry weight. Inner circle is total percent of animal and plant matter and outer circle is the percent of individual foods.

feeding for at least 15 min before they were collected to ensure that only birds that contained foods were taken; some birds were observed feeding for periods up to several hours. Esophageal food samples were preserved in 5% formalin or frozen and later sorted, identified, and counted. Foods were weighed wet and dry, and the data expressed as percent occurrence and aggregate percent dry weight. Samples were dried at 55° C to constant weight in a forced-air oven.

Results

Animal foods accounted for 96% (aggregate percent dry weight) of the diets of 18 Black Ducks (Figure 1). Periwinkles, amphipods, and Blue Mussels contributed 68% of the total dry weight, and Soft-shelled Clams (*Mya arenaria*), crabs (*Pinnixa sayana*), Clam Worms (*Nereis* spp.), and isopods (*Idotea baltica*) each accounted for approximately 6%. Sea Lettuce (*Ulva lactuca*) and other plant material comprised about 4% of the diet.

TABLE 1. Foods collected from Black Ducks in marine habitats of Maine during winter, 1983 and 1984.

	Percent occurrence		Aggregate percent dry weight	
	MN/JR[1] (N = 10)	RC/SR[1] (N = 8)	MN/JR (N = 10)	RC/SR (N = 8)
Animal				
Crangon septemspinosa	20		1	2
Cumacea		13		Tr
Edotea triloba	10		Tr	
Gammarus oceanicus	90	75	13	33
Idotea baltica	40		10	
Jaera marina	10	50	Tr	9
Littorina spp.	60	88	17	34
Mya arenaria	70	63	10	2
Mytilus edulis	70	38	38	Tr
Nassarius spp.	10		Tr	
Nereis spp.	20	13	7	4
Pinnixa sayana	50	13	3	10
Skenea planorbis	30		Tr	
Unknown	40	25	Tr	Tr
Plant				
Ulva lactuca		63		4
Zostera marina	20		Tr	
Unknown	10	13	Tr	4

[1]MN/JR = Mt. Desert Narrows/Jordan River, RC/SR = Raccoon Cove/Skillings River.
[2]Tr = trace (< 0.5 percent).

Although the diets were somewhat different between foraging areas, amphipods, periwinkles, Soft-shelled Clams and Blue Mussels were the foods most often consumed at each site (Table 1). Crabs occurred more often in the diet at MN/JR whereas isopods were a common food at RC/SR. Thirteen foods were consumed at MN/JR compared to 9 at RC/SR.

Discussion

Previous studies indicate that animal foods comprise most of the diet of Black Ducks wintering in coastal areas of the eastern United States and Canada (Mendall 1949; Hartman 1963; Grandy 1972b; Grandy and Hagar 1971). Hartman (1963) noted that the winter diet of Black Ducks in Maine contained 25% plant material, but only gizzards were examined and the importance of plant foods may have been overstated (Swanson and Bartonek 1970). Our study using only esophageal samples indicated that the diet of black ducks was much lower in plant material (4%), which is consistent

with the conclusion by Grandy (1972b) that plant food was not important to Black Ducks using marine habitats during winter. Besides methodology, the differences between Hartman's study and ours are probably related to variation in food resources. For example, invertebrates such as amphipods, clams, snails, and Blue Mussels are most important (Grandy 1972b, this study), although other animal foods (*see* Grandy 1972b), cordgrass (*Spartina* spp.) (Hartman 1963; Grandy 1972b), Eelgrass (Mendall 1984), plant seeds (Hartman 1963), and algae (Lynch 1939; Brodsky and Weatherhead 1985) are also eaten in small amounts.

The amount of plant food in the diets of wintering Black Ducks is most likely related to availability (Hartman 1963). For example, Black Ducks in RC/SR foraged among windrows of Sea Lettuce, and ate this alga along with associated invertebrates during the short period in early winter when tides deposited green leaves on the shore. Also, Black Ducks consumed a greater variety of foods at MN/JR, which probably reflected diversity of the food base. Flocks of wintering Black Ducks tended to forage in localized areas; therefore, differences among specific habitats could have influenced food availability, diet, and foraging behavior. Also, during extended periods of cold temperatures and ice, the availability of marine invertebrates is limited by the amount of ice in different tide zones (Hartman 1963; Albright 1981), thereby influencing the intensity of foraging and diet (Grandy 1972b).

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Changes in Caloric Content of the Amphipod *Gammarus oceanicus* Along the Coast of Maine

D. G. JORDE[1,2] and R. B. OWEN, JR.[1]

[1]240 Nutting Hall, University of Maine, Orono, Maine 04469
[2]Present address: U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland 20708

Jorde, D. G., and R. B. Owen, Jr. 1990. Changes in caloric content of the amphipod *Gammarus oceanicus* along the coast of Maine. Canadian Field-Naturalist 104(2): 303–304.

Caloric content of of the amphipod *Gammarus oceanicus* was highest (16.7 KJ/g) during May, and lowest (14.7 KJ/g) during December. The greatest increases of caloric content occurred during February and April, and the greatest decrease occurred during June. The high caloric content of amphipods during winter may benefit Black Ducks (*Anas rubripes*) and other waterfowl feeding on this food in marine habitats along the coast of Maine.

Key Words: Amphipods, *Gammarus oceanicus*, caloric content, invertebrates, Maine, waterfowl, Black Ducks, *Anas rubripes*.

The amphipod *Gammarus oceanicus* is an important food of Black Ducks, *Anas rubripes*, wintering in marine habitats of Maine (Albright 1981; Jorde 1986). Black Ducks and other waterfowl also forage on amphipods in inland habitats (Martin and Uhler 1939; Mendall 1949) and marine habitats (Mendall 1949; Hartman 1963; Grandy 1972) during fall and winter.

The objective of this study was to determine changes in the caloric content of the amphipod *Gammarus oceanicus* collected from marine habitats used by Black Ducks throughout the year.

Amphipods were collected monthly from rockweed ledges routinely used by Black Ducks as foraging sites in Mt. Desert Narrows along the central coast of Maine (Jorde 1986). Amphipods were dried to constant weight at 55° C in a forced-air drying oven, ground in a Wiley Mill, and caloric content of duplicate samples measured with an adiabatic calorimeter. The results were corrected for nitric acid production (Parr Instrument Co. 1969). Caloric values were converted to KJ/g by multiplying Kcal/g times 4.184 (American Society for Testing and Materials 1984: 25). Analysis of variance (Wilkinson 1986) was used to examine monthly changes in the caloric content of amphipods.

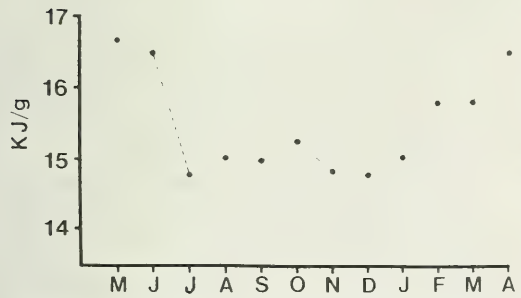

FIGURE 1. Monthly change in gross energy of *Gammarus oceanicus* collected at Mt. Desert Narrows during 1983 and 1984.

The gross energy of amphipods changed during the year (df = 1,11: $F = 11.63$; $P < 0.001$) (Figure 1). Gross energy was highest from April through June with a peak of 16.69 KJ/g during May. Energy content decreased in July and remained low until February. The lowest energy content in amphipods (14.77 KJ/g) occurred during December.

Foods of Black Ducks differ greatly in nutritional value and digestibility (Jorde and Owen 1988), which are important factors influencing choice. For example, amphipods are highly metabolizable compared to clams, mussels and periwinkles (Jorde and Owen 1988), and are readily available throughout much of the winter. The increase in caloric content of *Gammarus oceanicus* during winter may have an important energetic relationship to winter survival and breeding potential of Black Ducks and other waterfowl. Although more evidence is needed to examine this relationship, the results of this study indicate that the energy content of amphipods was lowest during December when fat reserves of Black Ducks were highest shortly after arrival on wintering areas. In February and March the energy content of amphipods increased when fat reserves of Black Ducks were decreasing (Reinecke et al. 1982) and energy expenditure was greatest (Jorde 1986). Amphipods contained the most energy when Black Ducks were accumulating protein (Reinecke et al. 1982) before migration to breeding areas during March and April.

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First Minke Whale, *Balaenoptera acutorostrata*, Record for James Bay

KENNETH F. ABRAHAM[1,3] and BURTON K. LIM[2]

[1]Ontario Ministry of Natural Resources, Box 3000, Cochrane, Ontario P0L 1C0
[2]Department of Mammalogy, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6
[3]Present address: Ontario Ministry of Natural Resources, Wildlife Research Section, Northern Unit, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario P7B 5E1

Abraham, Kenneth F., and Burton K. Lim. 1990. First Minke Whale, *Balaenoptera acutorostrata*, record for James Bay. Canadian Field-Naturalist 104(2): 304–305.

A Minke Whale carcass found 12 km south of Lakitusaki River mouth, Ontario is the first record of *Balaenoptera acutorostrata* for James Bay. This record is approximately 1200 km beyond Hudson Strait, the previously accepted westerly limit of the species range.

Key Words: Minke Whale, *Balaenoptera acutorostrata*, distribution, James Bay, Ontario.

Minke Whales (*Balaenoptera acutorostrata*) are distributed throughout the North Atlantic ocean in summer. The westerly limit of the species distribution has generally been accepted as the Hudson Strait. A record of a captured immature at Sugluk (= Saglouc, 62° 10′ N, 75° 40′ West), Quebec, and several sightings in Ungava Bay form the basis for this range (Sergeant 1963). Ungava Bay is mentioned as a probable summer migration destination (Banfield 1974).

On 7 June 1986, Ontario Ministry of Natural Resources (OMNR) pilots sighted a large whale carcass in a salt marsh on the northwestern James Bay coast between the Opinnagau River and Lakitusaki River, Ontario. This was within a few weeks of ice breakup on James Bay. The carcass appeared to be nearly intact but there were Polar Bear (*Ursus maritimus*) tracks at the site.

On 5 July 1986, the senior author pinpointed the carcass' location as 54°14′N, 82°21′W, 12 km south of the Lakitusaki River mouth, on the bank of a small tidal stream. On 31 July 1986, the site was visited by helicopter. At that time, the soft tissues of the carcass were in an advanced state of decomposition, although sections of throat pleats were still present. Some bones and baleen had been

scattered by scavenging animals. Measurements made then included: total length from anterior tip of rostrum to posterior tip of caudal fluke, 8.8 m; maximum skull width across zygomatic arch, 97 cm; total skull length, 185 cm; and mandible length, 182 cm. Several pieces of yellowish-white baleen were collected and photographs of the carcass were taken. In September 1987, the skeletal remains were collected and transported via aircraft, rail and truck to the Royal Ontario Museum (ROM). The measurements and photographs, the baleen length and color, the triangular rostrum and the throat pleats indicate that the specimen (ROM 94335) is *Balaenoptera acutorostrata* (Hall 1981).

The circumstances surrounding the whale's arrival in James Bay are unknown. Perhaps it simply followed a food source. Capelin (*Mallotus villosus*) constitute the primary food of Minke Whales off the coast of Newfoundland (Sergeant 1963). Sergeant suggested that the summer migration of Minke Whales in the western North Atlantic follows the spawning of Capelin. Capelin also occur in Hudson Bay and James Bay and spawn during June and July, usually on beaches (Leim and Scott 1966). The whale may have been stranded while feeding. A second possibility is that the whale was sick or in a weakened condition, and that its condition led to a stranding. A third possibility is that the whale died at sea somewhere in the species' previously documented range and drifted to its resting site. The latter seems highly improbable because the distance from Hudson Strait to James Bay is over 1200 km. Surface currents within this area (Dunbar 1951) and the number of shoals and islands would provide significant barriers to a drifting carcass. It is most likely that the whale arrived at James Bay alive.

There are no previous records of Minke Whales in Hudson Bay or James Bay. However, most whale strandings probably go unseen in this vast area because of the sparse human population of the region and most of the whale sightings that are made probably are not reported. There is also the possibility that sightings of Minke Whales are incorrectly attributed to one of the confirmed whale species. The Bowhead Whale (*Balaena mysticetus*) is the only confirmed baleen whale in Hudson Bay (Ross 1974). Other whales reported for the Ontario coast are the White Whale (*Delphinapterus leucas*), which is regular and locally common, and the Narwhal (*Monodon monoceros*), for which a single record exists (OMNR, unpublished data).

Although this single record does not confirm a range extension, the possibility of a restricted distribution of Minke Whales in James Bay and Hudson Bay should at least be considered.

Acknowledgments

J. Bell discovered the carcass and reported it to KFA. J. Dawson, T. Moser and T. Tacha helped with the initial field inspection. C. Davies, D. Ladouceur and J. Thompson deftly handled the odorous task of collecting and shipping the skeletal remains. R. L. Peterson provided facilities for cleaning the specimen and J. Borack assisted in the processing of the skeletal remains. C. Davies and J. L. Eger reviewed the manuscript. We thank all of them for their assistance in documenting this record.

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The Wing-moult of Cory's Shearwater, *Calonectris diomedea*, off Nova Scotia

R. G. B. BROWN

Canadian Wildlife Service, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2

Brown, R. G. B. 1990. The wing-moult of Cory's Shearwater, *Calonectris diomedea*, off Nova Scotia. Canadian Field-Naturalist 104(2): 306–307.

The progress of the moult of the primary flight-feathers of Cory's Shearwaters, *Calonectris diomedea*, is described from field observations made off southern Nova Scotia 15–31 August 1988 and from earlier cruises. Wing-moult begins after the end of June, and is in progress during August. It is theoretically possible that these birds were active breeders, foraging at long range from colonies in the Azores. However, the timing of their wing-moult makes this unlikely. Greater Shearwaters, *Puffinus gravis*, showed little sign of wing-moult in August, confirming the earlier conclusion that this species moults as soon as it arrives off Atlantic Canada in May–June.

Key Words: Cory's Shearwater, *Calonectris diomedea*, Greater Shearwater, *Puffinus gravis*, wing-moult, North Atlantic.

In a recent paper (Brown 1988), I summarised the seasonal moult of the primary flight-feathers ("wing-moult") in procellariid seabirds, observed off Atlantic Canada. The principal species were the Northern Fulmar, *Fulmarus glacialis*, and the Greater and Sooty shearwaters, *Puffinus gravis* and *P. griseus*. However, records of the Cory's Shearwater, *Calonectris diomedea*, were limited and inconclusive. This note presents further information on the wing-moult of Cory's Shearwater. It also gives data for the other species in Nova Scotian waters in August, a month not covered in the earlier paper.

Methods

My observations were made from CSS *Hudson* between 15-31 August 1988, in the course of Bedford Institute of Oceanography cruise 88-026. This began and ended in Dartmouth, Nova Scotia (*ca.* 44°32′N 63°27′W); however, most of the cruise was spent on NE Georges Bank (*ca.* 42°15′-41°43′N, 67°29′-66°46′W), > 170 km south of Nova Scotia.

Recording procedures followed Brown (1988). I checked the shearwaters when they first approached the ship. Moulting birds had a characteristic gap in the wing silhouette, just behind the carpal joint (e.g., Watson 1971: Figure 1). Birds with only one or two missing primaries were in "light" wing-moult, as opposed to the "heavy" moult of those with more extensive losses. Comparisons with specimens suggest that this technique underestimates the actual number of moulting birds (Stresemann and Stresemann 1970; Brown 1988). Probabilities are based on χ^2 tests with one degree of freedom, allowing for Yates' correction.

Results

Cory's Shearwater

Cory's Shearwater is a warm-water species that breeds in the Mediterranean and the eastern North Atlantic. It occurs off eastern North America from June to October, when it is most abundant between Cape Cod and southern Georges Bank (Palmer 1962; Cramp 1977; Powers 1983).

I checked 121 Cory's Shearwaters for wing-moult. It was present in 15 (12.4%) birds, six of which were in "heavy" moult. However, their "heavy" moult was not as extensive as that of Greater Shearwaters on the Grand Banks in June, when the latter often seemed to lose five or six of their inner primary feathers simultaneously (Brown 1988, and unpublished). The proportion of moulting Cory's Shearwaters was consistent with my previous observations at this season: a bird seen on 31 July 1985, and two on 29 August 1979, all in "heavy" moult (Brown 1988). By contrast, none of the 52 birds seen on Georges Bank on 25-26 June 1980, showed any sign of wing-moult. The difference between the ratios in June and July/August is significant ($\chi^2 = 6.977$, $p < 0.01$).

Other Species

Greater Shearwaters, the commonest procellariids off Nova Scotia in summer, are transequatorial migrants that breed in the subantarctic summer (Palmer 1962; Cramp 1977). Only 5 of the 269 (1.9%) birds checked in August 1988 were moulting their primaries; only one of these was in "heavy" moult. In χ^2 tests, this percentage did not differ from the ratios of 2/90 (2.2%), 2/287 (0.7%) and 0/217 off Nova Scotia in, respectively, July, October and November, or of 1/173 (0.5%) for the Labrador Sea in August (Brown 1988: Table 1). It was, however, significantly smaller than the ratios of 55/266 (20.7%) and 35/209 (16.7%) on the Scotian Shelf in May and June, respectively ($\chi^2 = 33.15$, and 45.94; $p < 0.001$), and of 450/679 (66.3%) on the Grand Banks in June ($\chi^2 = 317.89$; $p < 0.001$).

Of the other procellariids seen in 1988, wing-moult was present in two LL colour-morph

Northern Fulmars, but absent in two Sooty Shearwaters and five Manx Shearwaters, *Puffinus puffinus*.

Discussion

In Canadian Atlantic waters, wing-moult in Cory's Shearwater evidently begins after the end of June, and is in progress during August. The fact that only 12.4% of the August birds were moulting, suggests either that most of them had finished by then, or had not yet begun. Observations from July and September would clarify the point. This small percentage might also mean that, like the Greater Shearwaters (see above), relatively few Cory's moult off Nova Scotia. Their principal moulting area may be along the southern edge of Georges Bank, where the species is commonest (Powers 1983).

C. d. borealis, the subspecies found in the western Atlantic, breeds in the Azores, Madeira and the Salvage and Canary Islands (Palmer 1962; Cramp 1977; Godfrey 1986). Birds breeding on the Salvages lay at the beginning of June; the chicks hatch in late July, and are fed by their parents until October or later (Zino 1971). Presumably, the birds seen off Atlantic Canada in June and August are therefore non-breeders. However, this need not be so. It is also theoretically possible for birds breeding in the western Azores to forage off Nova Scotia. The distance is about 2700 km. Following Pennycuick's (1969: Figure 8) estimate for the fulmar, Cory's Shearwater's flight-speed is *ca.* 5 m.s-1. Birds on the Salvages incubate in six-day shifts (Zino 1971). If those in the Azores follow the same cycle, the off-duty parents could cross and return in two days, each way, and spend their other two days on Georges Bank. Birds foraging for their young could also do this, though there are no data on the intervals between feeds, as checks on the feasibility of the timetable. In both cases, the feeding advantages to be gained would have to outweigh the energetic expense of this long-distance foraging.

On the other hand, the timing of Cory's Shearwater's wing-moult in the western Atlantic does not support this suggestion. The birds presumably need a full set of primaries to maximise the efficiency of long-distance flight, and to avoid the additional, energetic demands of feather growth. Adult Greater, Sooty, and Manx shearwaters all delay their wing-moult until after their breeding seasons are over (Cramp 1977). Cory's Shearwaters breeding in the Mediterranean return to their colonies in March with new sets of wing-feathers (Mayaud 1949-1950) — a timing of moult that does not agree with that observed off Nova Scotia. These factors seem to rule out our August birds as active breeders from the Azores. This need not apply to the apparently non-moulting Cory's Shearwaters seen off Nova Scotia in June. However, given the tendency for the observation technique to underestimate the extent of wing-moult (Stresemann and Stresemann 1970; Brown 1988), it is more reasonable to assume that all the birds off Atlantic Canada are non-breeders, that moult their primaries and other flight feathers in the course of the summer.

My observations on Greater Shearwaters in 1988 support the conclusion that their wing-moult begins as soon as the birds arrive off Atlantic Canada in May and June. It is virtually completed by early July, or by early August off Labrador (Brown 1988).

Acknowledgments

I thank Captain L. Strom, W. G. Harrison, Chief Scientist, and the personnel of CSS *Hudson* for their help and hospitality during my cruise in August 1988. I am grateful to J. W. Chardine and E. H. J. Hiscock for their comments on the manuscript. This paper is an investigation associated with the programme "Studies of northern seabirds" of the Canadian Wildlife Service, Conservation and Protection Branch, Environment Canada (Report Number 234).

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News and Comment

Wolves of North America: Their Status, Biology and Management: A Conference Sponsored by the Canadian Wildlife Service and the Canadian Circumpolar Institute

The symposium will stress biology, conservation, and management based on the latest available information. Although the emphasis is on North American systems, topics from circumboreal regions of the world are included. Emphasis is on an update of the status and biology of the species. Cultural importance of wolves in modern society and on the economic impacts of wolves in various ecosystems will also be discussed.

Specific goals of the symposium are as follows:

To review the status of wolves in various parts of North America and to compare changes from 1981 to 1991 (dates between the first and second Wolf Symposia).

To update knowledge on the biology of wolves and to identify gaps in research on the species.

— To evaluate the adequacies of nature sanctuaries in North America in protecting functional ecosystems.

— To document the economic and environmental impact of wolf predation on hunting, livestock production, and tourism.

— To explore the links between carnivore conservation and evolving concepts of sustainable development in northern areas.

LUDWIG CARBYN
Wolf Symposium '91

University of Alberta, Canadian Circumpolar Institute, 215 Central Academic Building, Edmonton, Alberta T6G 2G1

Editor's Report for Volume 103 (1989)

A total of 101 manuscripts were submitted to *The Canadian Field-Naturalist* in 1989. Editing delays became publication delays and 103(1) was not mailed until 28 December 1989, with 102(2) and 103(3) mailed 16 and 31 July and (4) 26 September 1990. However, the purchase of a computer facilitated backlog clearing and manuscripts for all four issues of volume 104 and the first of 105 were already with printers before the last of 1989 issues were off the press.

Volume 103 totalled 656 pages, a decrease from the record 798 in volume 102. The largest issues (2 and 4) were each 180 pages, down from the single issue peak of 216 pages reached in 102(2). The number of research and observation contributions is summarized in Table 1, the totals for Book Reviews and New Titles in Table 2, and the distribution of published pages in Table 3. COSEWIC Status Reports on fish and marine mammals were again edited by Bob Campbell and appeared in 103(2) with the full cost of pages, tables, figures as well as reprints funded by the Department of Fisheries and Oceans. In addition, three other papers based on COSEWIC status reports, two on plants and one on an amphibian, also appeared in the volume. One tribute, to former Honorary Member Ibra L. Connors by D. B. O. Savile, was included, as was the address by W. O. Pruitt on the occasion of his receipt of the 1989 Northern Science Award from the Department of Indian Affairs and Northern Development. Liza Janssen recorded and acknowledged manuscripts and reviews and dispatched galleys in the first part of the year and Mickey Narraway took up this task at the end of the year when Liza was occupied full-time with duties for the herpetology section. Elizabeth Morton assisted in editing and marking manuscripts until she took up her new duties as Editor of the Ottawa Field-Naturalists's Club's regional journal, *Trail & Landscape*. Louis L'Arrivée again proof-read all galleys, Bill Cody covered all the business aspects of the journal and he and Lois bore the brunt of the enquiries about the status of impending issues with incredible good will. At M.O.M. Printers, Ottawa, Emile Holst and Eddie Finnigan and their staffs carried on under the uncertainty of when the next copy would arrive. E. Wilson Eedy coordinated and edited the Book Review section and Harvey

TABLE 1. Number of articles and notes published in *The Canadian-Field-Naturalist* Volume 103 (1989) by major field of study.

Subject	Articles	Notes	Total
Mammals	14	13	27
Birds	16	10	26
Amphibians and reptiles	2	2	4
Fish	15	2	17
Invertebrates	4	3	7
Plants	8	3	11
Total	59	33	92

Eleven of the included fish papers, one mammal and one invertebrate paper were part of the COSEWIC Fish and Marine Mammal subcommittee report series. Not included in these totals were the Fish and Marine Mammal subcommittee report, and a Tribute (to Ibra L. Conners), and the address at the 1989 Northern Science Award presentation.

TABLE 2. Number of reviews and new titles published in Book Review section of Volume 103 by topic.

	Reviews	New Titles
Zoology	74	133
Botany	31	84
Environment	21	106
Miscellaneous	12	32
Young Naturalists	2	95

TABLE 3. Number of pages published in *The Canadian Field-Naturalist* Volume 103 (1989) by section (number of manuscripts in parenthesis).

Issue number:	- 1 -	- 2 -	- 3 -	- 4 -	Total
Articles	84 (14)	140 (19)	67 (11)	114 (16)	405 (59)
Notes	15 (7)	10 (4)	38 (17)	10 (5)	73 (33)
News and Comment items	7 (6)	3 (5)	2 (3)	2 (1)	9 (15)
Other	—	—	9 (1)	8 (2)	17 (3)
Book Reviews*	45 (50)	26 (24)	35 (42)	24 (24)	130 (140)
Index	—	—	—	21 (1)	21 (1)
Advice to contributors	—	1 (1)	1 (1)	1 (1)	3 (3)
Total pages:	146	180	152	180	658

*total pages include both reviews and new titles but parenthesis figure includes only number of reviews.

Beck complied the Index. George LaRoi served as coordinator for the Biological Flora of Canada. Our panel of associate editors remained unchanged: A. J. Erskine (birds), W. O. Pruitt and C. G. Van Zyll de Jong (mammals), C. J. Jonkel (predator-prey relationships), D. E. McAllister (fish), C. D. Bird (botany). S. M. Smith (insects) and E. L. Bousfield (invertebrates). These were assisted by the following additional reviewers who commented on one or more manuscripts though the calendar year: J. D. Ambrose, W. B. Ballard, R. Banks, A. W. F. Banfield, J. C. Barlow, J. R. Bider, D. M. Bird, D. A. Boag, J. P. Bogart, G. Bartolotti, S. Boutin, R. D. Brannon, R. M. Brigham, R. J. Brooks, R. R. Campbell, R. W. Campbell, W. J. Cody, J. W. H. Conroy, F. Cooke, G. Corbett, P. R. Croskery, A. Crowder, E. H. Dunn, J. H. Enderson, D. W. Erickson, P. Frank, V. Geist, F. F. Gilbert, J. Gilhen, W. E. Godfrey, D. R. Gray, D. M. Green, R. H. Green, P. T. Gregory, J. Hall, F. H. Harrington, W. C. Harris, C. J. Henny, R. P. Higgins, B. Horejsi, R. D. James, A. R. Lock, L. A. Lowcock, H. G. Lumsden, A. W. Mansfield, W. B. McGillivray, R. McNeil, L. D. Mech, B. L. Monroe, M. T. Myres, D. Nagorsen, R. W. Nero, D. Nettleship, I. Newton, H. R. Ouellet, P. Paquet, D. B. Peakall, A. E. Peden, R. L. Peterson, G. Proulx, R. M. Raine, A. Reed, T. E. Reimchen, R. W. Risebrough, R. Robertson, F. W. Schueler, F. W. Scott, G. W. Scotter, M. V. Stalmaster, G. Stenson, A, Stewart, K. W. Stewart, R. W. Storer, G. B. Straley, B. K. Sullivan, R. Taylor, J. B. Theberge, R. D. Titman, A. Todd, K. Vermeer, S. Wendt, P J. Wheatherhead, C. M. White, G. G. Whitney, P. M. Youngman, S. C. Zoltai, R. G. Zweifel.

My thanks to Bill Gummer, Past President, Ron Harrison, President, and the Ottawa Field-Naturalists' Club Council, and to Ron Bedford and the Publications Committee of the OFNC for giving me consistent support. The National Museum of Natural Science continued to provide space and support in a year of difficulties with building conditions and impending transformation into a new crown corporation, the Canadian Museum of Nature, due in 1990. Joyce provided steadfast encouragement throughout the year.

FRANCIS R. COOK
Editor

Erratum: The Canadian Field-Naturalist 103(2)

In *The Canadian Field-Naturalist* 103(2) April-June 1989 on the inside back cover the "previous issue" to which the publication date of 28 December 1989 refers to 103(1) *not* "102(3)" as erroneously printed.

Notice of The Ottawa Field-Naturalists' Club 112th Annual Business Meeting 8 January 1991

The 112th Annual Business Meeting of the Ottawa Field-Naturalists' Club will be held in the auditorium of the Victoria Memorial Museum Building. Metcalfe and MacLeod streets, Ottawa, on Tuesday 8 January 1991 at 2000 h.

ELIZABETH FOX
Recording Secretary

Call for Nominations for the 1991 Council of The Ottawa Field-Naturalists' Club

A nominating committee has been chosen by the Council to nominate persons for election to offices and membership of the Council for the year 1991, as required by the Constitution.

We would like to remind Club members that they also may nominate candidates as officers and other members of Council. Such nominations require the signatures of the nominator and seconder, and a statement of willingness to serve in the specified position by the nominee. Nominations should be sent to the Nominating Committee, The Ottawa Field-Naturalists' Club no later than 1 December 1990.

It would be helpful if some relevant background on the proposed nominees were provided along with the suggested names.

BILL GUMMER
Chairman, Nominating Committee

The Ottawa Field-Naturalists' Club, Post Office Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5

Call for Nominations for the 1990 Ottawa Field–Naturalists' Club Awards

Nominations are requested from Club members for the following awards:

Honorary Membership
Member of the Year Award
Service Award
Conservation Award
Anne Hanes Natural History Award

Description of these awards is given in *The Canadian Field–Naturalist* 96(3): 367(1982).

With the exception of honorary members all nominees must be members in good standing.

Noominations and supporting rationale should be submitted no later than 15 December 1990 to

BILL GUMMER
Chairman, Nominating Committee

The Ottawa Field–Naturalists' Club, Post Office Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5

Book Reviews

ZOOLOGY

Peregrine Falcon Populations: Their Management and Recovery

Edited by Tom J. Cade, James H. Enderson, Carl G. Thelander, and Clayton M. White. 1988. The Peregrine Fund, Inc., Boise, Idaho. xviii + 949 pp., illus. $39.00 U.S. + $3.75 U.S. postage and handling.

Peregrine Falcons have long been symbolic, first of the "sport of kings" (falconry), more recently of the effects of synthetic chemicals on the environment, and more recently still, because of their recovery in many areas through intensive, often highly publicized, releases of captive-reared birds.

A conference held in Madison, Wisconsin in 1965 to address the decline has become a landmark event in environmental toxicology and the resulting proceedings *Peregrine Falcons: their biology and decline*, edited by Joseph J. Hickey, constitutes an environmental classic. The present tome is a collection of 81 papers presented at another conference held 20 years later in Sacramento to assess the current status of the peregrine and review the many findings of the research stimulated by the Wisconsin gathering. In addition to its 81 numbered chapters, the book contains seven commentaries, five appendices, a 46-page list of references cited, a detailed index, and several additional miscellaneous sections.

The book is divided into ten major "parts". A foreword by Roger Tory Peterson, preface by the editors and introduction by Cade precede the first part and outline events, biological and biopolitical, leading up to the two conferences. The first part consists of "keynote addresses" by three of the principal figures of the Madison conference, Joseph J. Hickey, Derek A. Ratcliff and Morlan W. Nelson. Hickey and Ratcliff reminisce on events that led to the first conference, providing important historical background to the plethora of chapters that follow. Nelson considers recent climatic events and speculates on their possible effects on peregrines and other life forms.

Parts 2 through 4 and 6 cover distribution and populations, parts 2 through 4 review the status of breeding populations since 1965 and part 6 considers migration and banding. Part 2 consists of 13 chapters and two commentaries on North America (including Greenland), part 3 of nine chapters and one commentary on Europe and part 4 of seven chapters and one commentary on the rest of the World. Although these papers updated status to 1985 when presented at the conference, several have also been updated further to 1987 prior to publication. Canada is represented by papers on Ungava, the Northwest Territories, the Yukon, and Queen Charlotte Islands, plus some comments in Lloyd Kiff's contribution on the continent as a whole and recoveries of Canadian-banded birds in other regions. Chapter 12 by Enderson and others on the Rocky Mountains and Colorado Plateau does not include the Canadian portion of the Rockies (nor are they included in chapters 38 and 53 also purporting to cover the Rocky Mountains). The general picture emerging in this section is that of a remarkable recovery over much of the continent, dampened by remaining high levels of DDE and less success in western areas. The section on Europe includes reviews of status in the British Isles, Fennoscandia, both Germanies, France, Italy and Spain, and parts of Czechoslovakia and Switzerland, followed by an overview by Ian Newton. Several of these review papers incorporate as yet unpublished data that should be published in greater detail elsewhere. Newton's comment on the lack of data from much of eastern Europe also applies to most of Asia, represented only by a chapter on *Falco* in general in Arabia and a very brief abstract on the Shaheen race in the Indian subcontinent. South America is represented by a chapter on the continent as a whole, followed by a three-page post-conference paper extending the known southern breeding range of the species, based on a 1986 trip to Tierra del Fuega. Australia is covered by one chapter; Africa by one on Kenya and one on "tropical" (i.e. sub-Saharan) Africa. A chapter on Fiji is the only contribution to status in the Pacific islands. The section on banding and migration is entirely North American. Chapter 47 on a migration along the west coast is the only one based partly on Canada, though recoveries of Canadian-banded birds are featured in several others.

In eleven chapters and two commentaries, part 5 considers what is known to date on the effects of synthetic chemicals on falcons. Although emphasis is on peregrines, several chapters include data on other falcons, especially American Kestrels, and sometimes other birds when findings on other species provides insight applicable or potentially applicable to peregrines. Like most of the rest of the book, most chapters in this section can be understood readily by lay readers, but some of the chemical and physiological aspects involved necessitate some rather technical passages, especially in Chapter 33 by Richard Fyfe and others. Ian Nisbet's review (Chapter 35) of the

possible role of dieldrin in population declines in North America in addition to the well known effects of DDE and the two commentaries at the end of part 5 (pp. 449–468) arguing against his views are of particular interest and would be useful starting points to any environmentalist seeking literature on chemical contamination. Nisbet believes that the role of dieldrin, which kills birds directly, in the rapidity of the decline of peregrines in certain areas may have been overlooked, although he does not doubt the role of DDE which acts primarily through reduced reproductive performance. Among many points of interest in part 5, one that particularly caught my attention was that in areas where a particular chemical is phased out generally, but retained longer locally, mortality resulting from chemical poisoning may actually increase for some time because prey in the most contaminated areas with higher pesticide loads may be most vulnerable to predation and thus selectively chosen by the predators. New data in part 5 is almost entirely North American, though its final chapter (43) reports on organochlorine residues and eggshell thinning in raptors in southern Africa.

Management techniques, especially propagation in captivity and reintroduction programs, are covered in 12 chapters in part 7, based on work in Canada, the U.S.A., Sweden and the two Germanies. Tom Cade's (chapter 50) historical summary of captive breeding of falcons pays tribute to several pioneers in Canada, especially in Alberta and British Columbia. One of those pioneers, Richard Fyfe, summarizes the Canadian Peregrine Falcon recovery program from 1967 to 1985 (chapter 56). Besides the well known captive breeding and release aspects of this work, Fyfe comments on efforts to sample prey on wintering grounds for pesticide residues and some of the bureaucratic frustrations he experienced. In another chapter (57), Lynn Oliphant and W. J. P. Thompson advocate the use of falconry techniques in reintroduction projects, as exemplified by experience in Saskatchewan. In Europe, some problems are posed by reintroduction efforts for another raptor in trouble, the Eagle Owl, and falcon enthusiasts disagree on the relative merits of reintroduction efforts and provision of artificial nest sites.

Basic biological research and theory are presented in parts 8 and 9 on population dynamics and geographic variation respectively. Part 8 includes a chapter (69) on the effects of large natural broods on parental mortality by Wayne Nelson, based on research on Langara Island, B.C., followed by a chapter on population biology in Keewatin District by Gordon Court and three other authors. Other chapters from Europe, North America and South America address various aspects of population ecology, natural regulation, dispersal, population turnover, dynamics of founder populations, limitations imposed by prey availability, behavioural differences among races, feeding behaviour, and wintering interactions, followed by a commentary by Ian Newton on population regulation. Part 9 consists of three chapters on taxonomic subjects. The first two require some knowledge of biochemical systematics to be understood readily, but the third, on races World-wide should interest most well travelled naturalists, especially if the reader compares illustrations of the 19 recognized races with their ranges on the World map on the book's inside covers.

Part 10, "Humanity and the Peregrine," is an eclectic collection of five chapters, two of which consider human impacts on the environment, problems these impacts pose to peregrines, and resulting convervation needs. One thoroughly documented chapter (80) by Williston Shor is an account and critique of "Operation Falcon," a U.S.-Canadian "sting" operation directed at smuggling. James Weaver's (chapter 78) essay on peregrines in relation "to contemporary falconry" is rather disappointing. As a defence of falconry, it is rather weak, relying primarily on the contribution of falconers to captive breeding and release projects. A much more comprehensive defence can be compiled by any reader working through other chapters in the book. If a discussion on the merits of falconry belongs in this book at all, it should be accompanied by some discussion of its negative impacts. Joseph Platt's (chapter 32) arguments that the falcons fare better under falconry in Arabia address one aspect of the issue, but nobody discusses the impacts of falconry on other birds, even though both Platt and David Remple (chapter 79) stress the favoured prey status of the Houbara Bustard (*Chlamydotis undulata*). Neither mention the marked declines this bustard has undergone, primarily because of the increased popularity of falconry in the Arab states (chapters by P. D. Goriup, pages 145-157 and A. Mian, pages 181-185 *in* Ecology and Conservation of Grassland Birds. Edited by P. D. Goriup. *International Council for Bird Preservation Technical Publication No. 7*, 1988). Surely, most people concerned over the plight of the peregrine should also be concerned over the bustards and other species. Remple's chapter consists both of a brief overview of Arab falconry and of avian diseases and avian medicine there. Weaver's brief account of migrant peregrines hunting migrant passerines on an island in the Gulf of Mexico should be expanded and published in greater detail elsewhere.

The production of *Peregrine Falcon Populations* has been careful, with relatively few printing errors for such a large book. Omission of reference sources by one author has resulted in six gaps in the comprehensive list of literature cited, but I noted only three other such omissions, three others with dates differing between text and the literature list and one with spelling of author differing.

A few other citations lack "a" or "b" necessary to distinguish between two references, and White (1976) on p. 368, table 10 requires initials to distinguish between two authors. Otherwise, I noted less than 20 "typographical" errors, all of which would be obvious to most readers except "Saanighton" (page 887) for Saanichton. There are also a few errors in cross-references and nine bird species mentioned in the text are not listed in the appendix of bird names. One has changed names from White-bellied Sea-Eagle to White-breasted Sea-Eagle between text and appendix. Grammatical errors are also infrequent, the most common being the use of a dash (short for "to") between various dates and numbers when an ampersand (short for "and") is required. "Between" is also used twice when "among" is intended and the redundancy "at the present time" (page 617) and grammatically atrocious "severely impacted" (page 590) managed to slip by the editors. More importantly, errors of substance are negligible, although Taiwan and Sri Lanka both appear under their old names of Formosa (page 590) and Ceylon (pages 798 and 807) in non-historical contexts. Although generally referenced thoroughly, the published paper by Dekker and Erickson (*Alberta Naturalist* 16: 1–3, 1986) on peregrine releases in Alberta and their better success in urban areas than in rural places would have been more accessible to readers than the unpublished report by Murphy mentioned on page 137, and would also be a useful addition to Fyfe's discussion of this topic on page 604. Similarly, the two "upper level" longevity records of at least 13 years and 9 years mentioned on page 481 would have been more meaningful to readers if placed in context of the record to date of 12 years, 3 months (Clapp et al. *Journal of Field Ornithology* 53: 81-124, 1982). Finally, the photographic plates in the middle of the book would have been more useful if more of them had been mentioned at appropriate places in the text.

In his treatment of the Peregrine Falcon in *Handbook of North American birds* volume 5, Ralph Palmer states that "no thoroughly comprehensive treatise on it exists" in spite of a huge volume of peregrine literature. This book is not that treatise, but does, as noted by its editors, make "a summary of current knowledge about the species" readily available to both scientists and lay naturalists. In this, the book is a credit to all concerned, but it also goes further in frequently pointing out gaps in knowledge that still need addressing. Like the magnificent bird it discusses, *Peregrine Falcon populations* will inspire considerably more research. It deserves to be at the fingertips of all raptor enthusiasts.

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M 1X4

World BirdBase: The World Birder's Database

By Santa Barbara Software Products, Santa Barbara. U.S. $99.00.

This new software is designed to provide a birder with the ability to input, store, manipulate, and output records of birds. The software comes with a complete list of all the birds in the world.

This program was first designed for records of the birds of the AOU checklist area only. It was sold as *BirdBase*. But demand from birders who have traveller outside North America caused the upgrading to the worldwide scope, and hence the new program *World BirdBase*.

The program contains the bird names in English and Scientific formats. The master list has the names in taxonomic order. Each species is identified by its common name, scientific order, family, genus and species names, and by a sequence number.

The program contains its own data base manager. This can be used for specific searches, such as for the records of a specific species, all records from a locale or all records from a period of time.

The bird list is based on James Clements' *Birds of the World*. The fourth edition of this book is to be published in 1990 and most of the changes that are to be made in the book have already been incorporated into *World BirdBase*.

The software runs on any MS-DOS computer that has at least 640 K bytes of RAM memory. It will not run on a 512 K machine. I tried it and there was just not enough space to hold the massive species list that is in memory at all times. I ran the software on an AMIGA computer with a 80286-based MS-DOS card running as a window in the multi-tasking environment. The software ran well. I fully expect that the software will run on 8086 and 8088 based machines, but at much slower rates. This review was typed on a word processor in one window on the AMIGA-DOS side of the computer

while BirdBase ran simultaneously in a PC window on the MS-DOS side. I worked back and forth between the programs and the operating systems with a click of the mouse. Such is the capability of a true multi-tasking computer.

The program brings the entire list of 9265 names into memory at the beginning of each operating session. This takes time, with an average of 120 seconds on my machine. The time taken up initially is counterbalanced by very fast searches later on. For eample, to go from the top of the list at Ostrich, to the bottom of the list at Thick-billed Raven, took only 6 seconds. This meant searching through all 241 pages of text to get to the last name in that time. However, a search through 241 pages of a Word Perfect file of bird names took 36.5 seconds.

When the program is fired up, a screen appears that has the first page of names. One moves through the bird names and the pages with the use of cursor keys. As one looks at a common name highlighted on the main screen, the scientific name for the species appears in a little window at the top of the screen. This method of displaying information is clearly presented and easy to understand.

The program has a built in capacity to deal with nine different lists actively. Some of these include: inclusive lifelist, country list, and home list. Information on a species in question is shown for each of the nine lists at the bottom of the active screen in some parts of the program. This is useful for comparing and updating lists. It enables one to look quickly at all the lists to see if the species has been seen before in that locale or circumstance.

The program has the built in ability to change the species names in the master list if they are split, combined, deleted or changed at some time in the future. This is very useful in order to avoid obsolescence of the main list.

The data base manager is designed to allow for unique searches. For example, "What new species did I see in California in 1987?", or "What species did I see from 1 July 1987 to 1 July 1988?", are easily answered questions. These lists can then be output to the screen, a printer or to a file. The printing utility works well, but slowly.

The entering of sightings is tedious and long. For each input, one must use many key strokes to get to a search menu. Then the species name must be typed, the name searched for, found and input into a list. This has to be repeated for each sighting of each species. There is no capability for a person to enter the names of species that he knows very well, and then have the computer do a search and compare set of functions. Each species must be searched for independently. It would be useful to be able to input information that is similar for each species only once and then have the computer assign this to each species.

However, the search function is powerful in that one need not know the entire name to do a search. A search can be done on sequences of letters from the first name or last name of either the English or Scientific names. This is very useful when one is not sure of the spelling of a complete name. It is also useful if one wants to do pattern matching, such as finding all the thrushes in the world.

The ability to find the name of one bird quickly in a list of 9265 species is very useful. In years past I kept a world checklist in Clements' book, third edition. It was quite tedious to look up the species in the index and then find it in the main body of the text. Even with all the key strokes I outlined above, such searches can now be done in a fraction of the time in the computer file.

The program has little capability for input from other data base managers. For example, I have many lists already in a manager called WATFILE+. I can not take the information from those files and put it into *BirdBase*. However, the reverse is possible. I can take lists out of *BirdBase* and put them into WATFILE+.

The real value of this package is probably in the computer list of Clements' Birds of the World. This a gold mine because it is possible to output the entire list into various forms that can be read into data base managers, spell checkers, and word processors.

For example, I output the list from BirdBase on the MS-DOS window into a Word Perfect word processing file on the AMIGA-DOS window with no problems. The names alone turned out to be a document 525 pages long after spaces between the names were added to the 241 page list in the database. I can see the potential to use the names within a spell checker so that never again will one have a bird name spelled incorrectly in a report. It should be possible to write macros in the more sophisticated word processing programs so that one could type in the common name into a document and then have the computer go out and find the equivalent scientific name from a master list.

Those users with experience with sophisticated data base managers would probably not want to stick with the data base manager that comes with the software. However it is easy to strip the bird list from the program and input it into any of those other programs. Users without experience with data base managers should find the canned one included with this program to be satisfactory.

This software was designed for the keen birder. However, it has a wider professional utility. Biologists who deal with reports of field observations, compile bird lists for specific sites or undertake comparative analyses of species compositions between sites should find this software

to be of use. The people in the environmental impact business should find it to be particularly useful.

The price is low. At U.S. $99.00, the software is a bargain.

PAUL F. J. EAGLES

Department of Recreation and Leisure Studies, University of Waterloo, Waterloo, Ontario N2L 3G1

Acta XIX Congressus Internationalis Ornithologici

Edited by H. Ouellet. 1988. National Museum of Natural Sciences and University of Ottawa Press, Ottawa. 2815 pp. (2 volumes). $175 plus postage 5% in Canada and 10% elsewhere.

In June 1986 Ottawa was host to the 19th International Ornithological Congress. This major scientific event attracted researchers from around the world. It gave neophyte scientists and some dedicated amateurs an opportunity to meet the ultra-famous like Peterson, Sharrock, and others, as well as the leaders of academia, museums, and research institutes. For a week these people attended seminars and were engrossed in the details of ornithology's leading edge. (They did find time to play. There were five field trips a day from early morning to the start of the congress proceedings. All of these were well attended. The enthusiasm shown for birds by foreign professionals such as Killdeer, Redwinged Blackbird, and so on was as wild as that of any group of amateurs!)

The Acta is a compilation of all the papers presented during the congress, plus a summary of the various business meetings. As might be expected from such a world gathering, the output is tremendous. This work is published in two volumes with a total of 2815 pages. It covers 233 papers given in 50 symposia, two thirds of which have an introduction or conclusion. There are five major plenary papers. The authors came from 35 countries, but almost all the papers are in English. About 2% are in French, the only other language used. The biggest contribution came from the United States (almost 30%); Great Britain (14%) and Germany (8%) were other countries supplying a major input. Canada's input was a respectable 12%. The remaining papers were from a wider range of countries. I was specially impressed by the input from some of the less wealthy countries like Rwanda, Thailand, and Uganda.

The breadth of subjects in the 50 symposia is so expansive it is easier to comment on what's not there. Anatomy, geographical distribution, new taxonomy, and conservation are not covered directly. Most of the papers concentrate on the detailed aspects of a small section of avian science. A few papers like those giving biographies of famed naturalists are easy for the non-scientist reader, while others, say on plumage evolution in chicks, would require the use of a good biological dictionary for those not currently in the field. Suffice it to say the majority will only be appreciated by those who are at the leading edge of research. In some cases the work may seem esoteric in the face of today's urgent problems. However it is these thin slices of high science that we need to build the in-depth knowledge required to understand and protect the world's birds.

The papers vary considerably in complexity. Some are fairly straight-forward accounts of field or laboratory work, drawing the most logical of conclusions from these new data. The most complex of papers involve not only biology but also other disciplines, such as mathematics and physics; displaying the increasing trend towards multidisciplinary studies. In short, this is a collection of papers by scientists for other equally skilled scientists. It will be a most-valuable reference for many years to come. Ph.D. students will find it a particularly compact reference although the price may mean that they will be using a library copy.

One last point, I am impressed with the speed at which these works were published. It is a credit to the editors and the cooperation of the authors and others involved, that they did not allow the publishing effort to lose steam after the Congress was over.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

Bird Conservation 3

Edited by Jerome A. Jackson. 1988. The University of Wisconsin Press, Madison. viii + 177 pp., illus. Cloth U.S. $17.50; paper U.S. $12.95.

Bird Conservation is published as a periodical of the U.S. section of the International Council for Bird Preservation. Although intended as an annual, this third issue appeared three years after the second (1985), which in turn followed two years after the first (1983). As noted in reviews of the first two issues by Stephen Gawn and me (*Canadian*

Field-Naturalist 99: 556, 1985, and 101: 311–312, 1987), each volume consists of a main section of several papers on a particular theme, followed by a shorter section on news and updates, and a review section. This third issue contains only one conservation update (by L. L. Short on woodpeckers) and one book review instead of the list of recent literature that occupied about a dozen pages in each of the first two volumes. An index to bird species (both English and scientific names) is a useful new feature.

The theme of this volume is "the past, present and future of North American forest ecosystems and their avifaunas," covered through a brief preface by Jackson and seven major review papers. Six of these papers cover specific forest types in particular areas of the U.S.A., while the seventh by Custis A. Adkisson reviews the biology and conservation concerns of cavity-nesting birds in North America generally. Although most of the contents relate to forests in the U.S.A., the biological principles, patterns of forest use, and conservation concerns discussed apply equally well to Canada. Patterns of decline, increase, and fluctuation in response to logging, forest clearing, and other human activities appear repeatedly. Naturalists in southern Ontario will relate closely with concerns over firewood harvesting practices in Ponderosa Pine forests of the southwestern U.S., while concerns over such restricted species as the Chestnut-backed Chickadee in the U.S. Pacific Northwest will be shared in British Columbia.

Important themes expressed at least once, and more often throughout, include the similarity of effects of logging to those of fire *except in scale*, the effects of fragmentation and reduction of species diversity imposed by even-aged plantations, the inability of some species to adapt to artificial structures, and the greater vulnerability of species with narrow ranges of habitat use. Naturalists fighting to save remnants of ancient forests in British Columbia, Ontario, and elsewhere will find Adkisson's comment that current U.S. forest management policies "amount to a disaster for any organism that depends on older-growth forest" equally applicable to Canadian provincial governments. His comment that current practices of attempting to manage species instead of ecosystems are "reminiscent of trying to control many small brush fires simultaneously" could be applied to *any* habitat anywhere.

Adkisson's general review could well have been expanded to cover several aspects more thoroughly, but offers a useful brief summary of the advantages and disadvantages of hole-nesting, the history of forests in North America in relation to settlement by Europeans, and the various impacts that forestry practices have on hole-nesting bird populations. The other chapters are also written well and are generally thorough, offering many insights into subtle and not so subtle effects of human activities in forests on bird populations. In discussing the subalpine forest of the southern Appalachians, George A. Hall offers the intriguing suggstion that the mysterious "Blue Mountain Warbler" of Audubon and Wilson may have been a localized endemic that disappeared with the elimination of 90% of this habitat.

The only major topic scarcely covered in the book concerns the effects of acid precipitation on forest birds, a topic barely researched by the time (1985) that at least some of the manuscripts were written. Readers interested in this aspect should consult a paper by R. K. Schreiber and J. R. Newman published about the same time as this book (*Conservation Biology* 2: 249–259, 1988). Hall's suggestion that acid *fog* may have a greater effect on spruce at higher elevations would be well worth investigating in other fog-shrouded areas.

The reference by Lowery (1974) cited on page 146 of Jackson's paper on southeastern pine forests is missing from his list of literature cited and three papers listed in the literature cited for two chapters appear not to have been cited in the text. Otherwise, I found few proof-reading lapses, most involving dates or spellings that differ between text and literature cited.

Naturalists interested in forest ecosystems and their conservation will find an excellent information source in this book. It continues the high quality achieved in the first two volumes.

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M 1X4

Enjoying the Birds of the Ottawa Valley

By John Sankey. 1988. Published by the author. Ottawa. 116 pp. Paperback. $7.95.

This is undoubtedly the most difficult book that I have reviewed in several years because of its scope. The "Contents" gives an accurate idea of the topics discussed by the author of this small book. The list is extensive and contains a diversity of subjects listed under seven main headings under which the author rambles widely. The themes range from a very brief discussion about the physical features of the Ottawa Valley, "birds around the home", "birds in nature", "getting

serious about birds", etc., to "probability of species observation". Under these headings, several subheadings allow the author to treat almost anything that deals with birds such as choosing binoculars, identification, species throughout the year, photography, song recording, study projects, and bird navigation, to name only a few. Most of these topics are covered superficially but contain information that should interest the average bird watcher or the person new to the Ottawa region.

If a reader is fairly knowledgeable about birds it will be annoying and disconcerting to find inaccuracies in a number of facts. Otherwise the reading is generally enjoyable and the author can often be humorous, which contributes to retain the reader' interest. I felt rather frustrated because so many topics are covered too superficially to be of real use to a reader with even a modest knowledge about birds but the imprecision or ambiguousness of several statements is a more serious deficiency.

Persons new to bird watching or not familiar with the Ottawa region will probably find this book useful. Others will probably agree with my comments, or, if they are not too critical, may enjoy reading it and find it rewarding. Regardless of my comments, considering the price, the risk of being disappointed in the purchase is not very great!

HENRI OUELLETT

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Canada, K1P 6P4

The Atlas of Breeding Birds of New York State

Edited by R. Andrle and J. Carroll. 1988. Cornell University Press, Ithaca. 551 pp., Illus. U.S. $29.95; map overlays U.S. $9.95.

This is New York's contribution to the growing list of breeding bird atlases. The well-over four thousand people who contributed to this effort should feel proud of the final result. The format follows that of other atlases, in that there is a map on the right-hand page with text and a black-and-white drawing on the left. The map is clear and provides an instant understanding of the breeding birds distribution. The accompanying text is well written and informative. The three inch square black-and-white drawings are delightful.

Even a quick scan of the maps will be enough to bring out some major features. The Long Island area gives New York a slice of maritime habitat and means these fortunate Americans can add egrets, ibis, rails,and seaside sparrows to their list of breeders. Relatively few miles north they can enjoy the grandeur of the Adirondacks and a group of boreal birds. Birds we normally think of as "Canadian" like, Grey Jay, Boreal Chickadee, three-toed woodpeckers, flycatchers, and others all live in this rugged ecozone. This diveristy of habitat means that New York's list reaches 242. This compares favourably with the Ontario Atlas's 292 breeding birds, despite the enormous size difference (Ontario is over eight times bigger). As might be expected there is little difference in species between Southern Ontario and New York. Ontario has a few extra boreal species and New York gains with it's maritime specialities. The big difference, however, is in the birds that nest in Ontario's north. The northern loons, geese and ducks, shorebirds, and the tundra passerines, along with some western species that make it into Ontario are what make this list longer. I was a little surprised that generally the proportion of confirmed nesters was not higher than in Ontario. Considering they had three times as many people in one-eighth the area I expected this greater coverage to translate in a better confirmation rate. I was also puzzled by New York's lower species diversity. Most of the squares have 75 species or less in comparison to the 80-100 species which is typical of Southern Ontario. Some of this may be due to the difference in atlaser effort (average 92 hours per atlasser in Ontario compared to 47 hours in New York).

This Atlas, like others, has sections on the survey methods, the ecozones of the region, and a list of participants. In addition, there is a chapter on prehistoric birds. This offers the reader a different perspective. I was amazed to learn that the Californian Condor once graced New York's skies.

The atlas comes with a package of eight transparent overlays. These show County/Federal and State Wildlife areas; ecozones; elevations, river systems; forest types, forest cover, mean July temperature, and mean precipitation. These overlays help the reader see the relationships between the breeding distribution and the overlay feature. For example, I tried the rainfall overlay on several ground-nesting birds and not surprisingly they tended to avoid the areas of high rainfall. The ecozone overlay provides some of the obvious relationships. With it I found the Red-bellied Woodpecker avoids the highlands, whereas the Yellow bellied Sapsucker avoids the plains.

I find these atlases very useful in planning my birding activities. I have used the British, French, and Ontario atlases on several occasions and have been more successful in seeing interesting birds as a result, so I am pleased to see each new one

published. Living, as I do, close to New York State I am especially pleased with this excellent book and I am certain it will get well used in the coming years.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

Birds of the Rocky Mountains: With Particular Reference to National Parks in the Northern Rocky Mountain Region

By P. A. Johnsgard. 1986. Colorado Associated University Press, Boulder, Colorado. xi + 504 pp., illus. U.S. $16.95.

Despite an abundance of popular guides to the natural history of the Rocky Mountains, there is still no comprehensive treatment of its birdlife. Therefore, I looked forward to seeing this book. I anticipated a well-written, adequately researched, and useful reference work. After a cursory reading however, I was disappointed. Coverage is incomplete, the text is filled with inconsistencies and errors, and despite a list of 149 references, is still incompletely researched for the area covered. In short the book is hastily prepared and poorly edited.

The book consists of four main sections: an introduction, which includes a checklist of birds of the Rocky Mountain parks (54 pp.); species accounts (362 pp.); regional, local, and individual species references (46 pp.); and an appendix on abundance and breeding information for U.S. and Canadian national parks (36 pp.).

The scope of the book includes about 350 000 square miles of Rocky Mountains between 40° and 52°N latitude, or roughly the area between northern Colorado and southern Alberta and British Columbia. Western Idaho and eastern Montana and Wyoming are the western and eastern limits respectively. Eight national parks occur within the area, and it is these in which the avifauna is highlighted. Four parks occur in Canada (Banff/Jasper, Yoho, Kootenay, and Waterton Lakes) and four in the United States (Glacier, Grand Teton, Rocky Mountain, and Yellowstone).

The introductory section adequately deals with the physiography, climate, and vegetation of the U.S. parks but ignores parks in British Columbia and only briefly mentions Alberta parks. No references are given. Five sections follow, each with its own list of birds. The lists are confusing and lack consistency.

The first two "typical Rocky Mountain avifauna" and "widespread western avaifauna" are broken down into three categories: water-related, forest-related, and widespread and other species. In the former list, species are included on the basis of their widespread occurrence in the national parks (reported from at least five of the eight parks). The latter list includes species which are distributed throughout the entire region, but not necessarily in all of the national parks. The differences between the lists are subtle, and to most people, confusing. Overlap between lists is great, and there is no consideration of seasonality or status.

A list of "substrate-dependent avifauna" follows which is incomplete and inaccurate. Species are listed under eight "substrates", one of which is "fish dependent species" and concerns prey, not breeding sites. Obvious species have been overlooked despite being mentioned in the species accounts part of the book. For example, Common Raven is not listed with "cliff-nesting species", and American Robin, Tree and Violet-green swallow, Chimney Swift, and Common Nighthawk are omitted from "human-made structures".

The final list is the checklist of birds for the eight national parks. Again, inconsistencies appear. In the beginning of the book, the author states ". . . total of 354 species are included in the book". But in the checklist only 346 species are included while another checklist, in the appendix, shows 355 species. Only one list is needed. The appendix checklist is probably most useful to birdwatchers, as it gives status and abundance for each species by season. Again, Dinosaur National Monument has been added to only one of the lists. In one list, Banff/Jasper are listed together, while in the other list only Banff is included. Occurrence and abundance codes are indicated by letters (e.g., A = abundant, C = common, etc.), but their use throughout the book is confusing and none are explained. The reader should know the difference between an "abundant" and "common" species. As well, the duplicate use of symbols and codes is very confusing. For example, "R" can mean "breeding permanent resident" or "rare" and "V" either a "vagrant, out of normal range" or "accidental."

The last section in the introduction includes details for "major bird-watching areas." The eight national parks are included, but most readers would not assume from the title of the book that another 17 sites are discussed including national monuments, wildlife refuges, and a bison range!

The bulk of the book, (72%) is in the species accounts, each of which consistently contains six sections, namely identification, status, habitats

and ecology, seasonality, comments, and suggested reading. Research for the book started in 1982. Only a couple of references were selected in 1983, even though the book was not published until 1986. Each species account is accompanied by two figures. One is a coded distributional status presented in grid or "latilong" form following Skaar (1975), which is not listed in the references. The other is a shaded general distributional map. It is not clear what different shading refers to without reference back to page 38. The legend should be at the beginning of the species accounts.

I question the value of including information on identification, especially when so many excellent field guides are available today. Up to 24% of some accounts are used up by this category. Personally, I would have enjoyed more information on species' ecology. Also, the chance of errors and inadequate information would be reduced.

The status text should be read with caution. For example, under Black-crowned Night-Heron (page 74) the author states ". . . the only park where breeding has been reported is Yellowstone . . .", but in the accompanying latilong figure the code "S" (= breeding summer resident) occurs in 8 of 36 grids.

The remaining subsections on habitat and ecology, seasonality, comments, and suggested reading, although brief, are adequate for the U.S. parks but are incomplete for Canadian, and in particular British Columbia, parks. In fact, they are seldom mentioned, and when they are, information is frequently incorrect.

Over 10% of the book is taken up by accounts of vagrant species, most of which add little to Rocky Mountain avifauna. The 52 species are already listed, with statuses, in the appendix checklist. Even presented in bar graph form as a calendar would be more useful than devoting a full page to each of them.

Personally, the suggested reading section is the most useful. However, it is by no means complete and without errors. It also does not necessarily include the most relevant literature for the species and the Rocky Mountains region. Anderson (1976) and Maher (1974) would be more appropriate references for Long-tailed Jaeger than those listed. Frequently European literature is included instead of available literature from North America. For example, Meehan (1980) and Meehan and Richie (1982) are overlooked for Northern Hawk-Owl and Bondrup-Nielson (1978), Meehan (1980), and Palmer and Ryder (1984) for the Boreal Owl. In addition, a few major references are not included (e.g. Walkinshaw 1949 for Sandhill Crane).

In some accounts, references are listed by journal rather than by author. This is frustrating because they cannot be located in the book. Also, there are errors in cross-referencing.

All references are separated into two sections — one for the parks and general Rocky Mountains region and another for individual species. The former is subdivided into seven parts, so if the reader wants to find Godfrey (1950) eight separate lists must be searched. References to British Columbia are omitted despite the availability of a provincial bibliography which includes at least 35 articles on its parks (see Campbell et al. 1979). For those interested, another bibliography containing 80 additional references to British Columbia's Rocky Mountain parks is available (see Campbell et al. 1988).

The use and spelling of common names throughout the entire book is inconsistent. In some cases, the author followed the new American Ornithologists' Union (1983) and its supplements (1984, 1985) and in other cases, old terminology is used. I checked seven references to Northern Pygmy-Owl and all were spelled incorrectly. In nine references to American White Pelican, four different spellings were used and only five were correct. Inconsistencies also occurred in headings for species accounts. In some, old and new names appeared (e.g. Great [Common] Egret, Tundra [Whistling] Swan), while in others, new names identified species and old names were buried in the comments sections (e.g. Merlin/Pigeon Hawk, Northern Harrier/Marsh Hawk). Errors in scientific names were far less numerous (e.g. *Falco sparvenius*).

Poor editing is also evident in other parts of the book. Readers are not sure whether the national park in Alberta is called Watertown or Waterton Lakes. In the same paragraph on page 35 it is spelled both ways! And in the index the Common Raven account is not to be found on page 247 but on page 277.

My final criticism concerns the 24 pages of colour plates. The Red-tailed Hawk in plate 9 is not an adult as stated but an immature. The names for plates 22 and 23 should be reversed, subspecies names on plates 15 and 42 should be replaced by species names (e.g. Greater Sandhill Crane = Sandhill Crane) and the chick isn't visible in plate 15 although it is mentioned in the caption.

I cannot recommend this book to anyone, although cautious ornithologists and informed birdwatchers may be able to glean some useful information. The book requires a thorough revision, most of which can be accomplished by an experienced editor, before it may be used as a reference book. I cannot help but think that the author, in his haste to produce yet another book, must be disappointed with the final product.

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R. WAYNE CAMPBELL

Royal British Columbia Museum, Victoria, British Columbia V8V 1X4

Birding by Ear: A Guide to Bird-Song Identification (Eastern/Central)

By Richard K. Walton and Robert W. Lawson. 1989. Houghton Miffin (Canadian Distributor: Thomas Allen & Son, Markham). 3 Double-sided Cassettes and one 64 pp. booklet.

The identification of bird songs and calls has always presented major challenges to birders. Unlike visual stimuli, it is difficult to be selective with sounds: the listener has to sort out a multitude of competing noises, all superimposed on one another. Then totally unrelated species often sing very similar songs, and the individual variations in dialect and presentation far exceed the differences normally encountered with bird plumages. Add to all this wide variations in hearing — what you hear is not necessarily the same as that heard by someone else — and the difficulty in communicating information on bird sounds, and you have one of the more demanding aspects of birds in the field, whether your interest is in birding or in ornithological field work.

Hence it is not surprising that birdsong records and tapes have become well-established and vital tools to the ornithological community, professional and amateur alike. No longer is it necessary to try to figure out what some author meant by a "sizzling trill", or to try to interpret a sequence of puzzling symbols which purport to represent a song. But the problem of distinguishing the song of one species from another remains, and the recordings sometimes seem to make that often complex problem even more difficult, as they present a bewildering array of song variations and nuances, while providing little structure to aid in learning.

This latest addition to the Peterson Field Guide series — number 38 — is the first set of tapes to attack this challenge. The three cassettes divide the songs of 85 "widespread and vocal" birds into 17 categories, based on shared features in their sounds or patterns. Each song is introduced by a commentary pointing out its characteristic features, and the differences that distinguish it from similar songs. The second side of the last cassette rearranges all the songs into 10 habitat groupings, and challenges the listener to identify each song in turn. An accompanying booklet lists each species covered, with brief notes on the bird's habitat and voice, repeating some of the material presented on the tape, together with a small line sketch, and with space available for the user's own notes. There is also a short bibliography and both alphabetic and phonetic indices, the latter giving references to the species' notes or song (for example, 'chick-burr' for the Scarlet Tanager). Cassettes and booklet together fit into a compact, pocket-sized and book-style plastic case.

Birding by Ear is both an exciting advance and a missed opportunity. These cassettes will indeed give the beginner some valuable basic tools to sort out various songs, and with some perseverance the

user should be able to build up a familarity with the ones selected. The introductory section, with a brief discussion on sound production in birds, and on some techniques which can be used in identification, is very useful background. Many of the categories used will be familiar to all who have wrestled with birdsong recognition.

But if you turn to these tapes hoping for assistance in sorting out, for example, Solitary and Philadelphia Vireo songs, you will be disappointed. While it could be argued that these species are not common enough to rate inclusion, you will even search in vain for a comparison of Red-breasted and White-breasted Nuthatches. In fact observers (listeners?) in most parts of Canada, where White-breasted Nuthatches are rare and Red-breasted are common, will be dismayed to find only the White-breasted is on these tapes — together with other such "commoners" as Summer Tanagers, Tufted Titmice, Chuck-will's-widows, Kentucky Warblers and White-eyed Vireos. While this publication is marketed in Canada, the authors didn't really have us in mind. A Canadian birder using it must always remember that the song selections are often rather inappropriate, and even the habitat groupings may present a rather unusual mix of birds.

The more experienced birder will be disappointed at a much more basic level. This is not the sound equivalent of Peterson's Eastern Guide — it is more analagous to the series of First Guides, and like them it sometimes over-simplifies to the point of being misleading. Not only are a limited number of species presented, but a limited number of song variations are given. Those song sequences of Northern Cardinal, Tufted Titmouse, Carolina Wren, and Kentucky Warbler which can be confused are not discussed; rather the first two and last two species only are grouped. Warblers are limited to nine species — including Kentucky and Hooded — and the potentially tricky separation of Black-throated Green and Black-throated Blue; or Yellow and Chestnut-sided Warblers goes unmentioned, as indeed do the second species in each of the above pairings. Similarly, other widespread and familiar migrants are missing.
Because the selection of species is limited, the selection of categories is limited too, and again opportunity is missed — analysis of the Song Sparrow song pattern can be a useful jumping-off point for a discussion of other sparrows with similar, rather complex songs. But here Song Sparrow appears alone, grouped as a "Commoner", which does nothing to sharpen the listener's awareness of the song pattern, let alone encourage its use as a learning tool for other songs.

Yet space was available on these tapes for a more comprehensive treatment. Much is devoted to the voice commentary which is rather discursive, and varies from being rather cute (some of the groupings are "sing-songers" and "high-pitchers") to wordy (Eastern Wood-Peewee song is important because the bird has a "long visual profile", whatever that means!). There is also much repetition, necessary if one is to learn, but perhaps less necessary on a tape, which can be played back. The selection of material could also perhaps be better, as a fair amount of space is devoted to the songs and calls of such easy-to-recognize species as Whip-poor-will, Killdeer, Northern Bobwhite and American Crow.

Much of this begs the question of when an observer is ready to learn songs and calls in an organized manner. My own experience is that the beginner is usually too busy wrestling with the visual problems birding presents to be prepared to devote much effort to sounds, vital though they are. By the time he or she is ready to graduate to an organized attack on birdsong some level of sophistication has been achieved, and the individual is no longer content to be presented with a limited treatment. Perhaps this work will change all that, and we will find beginners learning both visual and auditory "field marks" in parallel. If so, it will be a valuable contribution that will accelerate even more the learning of field techniques.

Who, then, should purchase these tapes? As an excellent introduction to the often bewildering cacaphony of bird notes, and indeed the only ones of their kind in the field, they will be useful to anyone who has little or no experience with the techniques of analysing song patterns and of grouping similar songs. The principles used here have broad application, and could give the beginner the tools to go on and develop comparisons of his or her own. The Canadian user, particularly, should be aware that this will be necessary, as the selection does have a southern bias and about 20% of the featured songs are unlikely to be heard with regularity anywhere away from south-western Ontario. Hence the comparisons related to this group are also rather irrelevant to the Canadian user, who will discover the problems are with other species not included on the tapes. By the same token, the user should beware of concluding that matching a song to a pairing on the tapes — say, Black-and-white Warbler and Ovenbird — identifies the bird. You may be listening to a Blackburian Warbler!

The more experienced birder, already familiar with song recognition techniques, will probably pick up some useful information on the species covered here — I found a good additional pointer in separating House and Purple Finch songs — but this is likely to be limited. Such persons would probably be better advised to spend time with the

many more comprehensive recordings of birdsongs that are available, working out their own groupings and comparisons.

CLIVE E. GOODWIN

45 LaRose Ave., #103, Weston, Ontario M9P 1A8

The American Crow and the Common Raven

By Lawrence Kilham. Texas A&M University Press, College Station. 255 pp., illus. U.S. $29.50.

Lawrence Kilham, as many readers know, observes carefully, reads widely, and writes well. Those who have enjoyed Kilham's recent, more general book, *On Watching Birds* (reviewed in *Canadian Field-Naturalist* 103(4): 615, 1989) will find his book about crows and ravens to have similar appeal. Kilham, a university professor, does not talk down to his audience. In fact, his language at times can be technical — for example, he used 'nictitans' without definition.

To most of us who claim to have an interest in nature, a crow sighting is a "ho-hum" event, but not so for Kilham, who describes the crow as "omnivorous, intelligent, resourceful, and cooperative." What he can learn from the behavior of unmarked birds is somewhat of an eye-opener. Kilham's anecdotes demonstrate that the crow is among the canniest of birds, with a considerable capacity for play and learning. In fourteen chapters, we learn about crow behavior in all seasons, including foraging, territory, food storage, breeding cycle, and nest defense, both in Florida and New Hampshire. Kilham describes the social system, emphasizing his original and important information about cooperative breeding. In Florida the average pair of crows had 5.2 non-breeding potential helpers sharing the same territory; in thirteen groups, there were 50 such crows in adult plumage and 18 in yearling plumage.

Fun to read are the three chapters of anecdotes dealing mainly with three hand-raised crows and two hand-raised ravens. Unfortunately, since Kilham fails to warn of the inherent dangers in such unnatural adoptions, his accounts are apt to encourage readers to take wild birds as pets.

Not only does Kilham not band birds, but he seems to disapprove of those who do. Although he mentions what has been learned about helper behaviour in other corvids, especially the Scrub Jay, he does not give credit to the long-term studies of color-banded birds which gained this detailed knowledge.

Only one chapter deals with the behaviour of ravens in the wild, telling of their depredations on nests of other birds, and of their food caching in deep snow in winter. Ravens have become re-established in New Hampshire only since the 1950s.

If you are interested in bird behaviour, you will enjoy reading this book. Joan Waltermire's sketches nicely complement the text.

C. STUART HOUSTON

863 University Drive, Saskatoon, Saskatchewan, Canada S7N 0J8

The Sparrows

By Denis Summers-Smith. 1988. Poyser (Distributed by Buteo, Vermillion, South Dakota). 342 pp., illus. + plates. U.S. $57.50.

This monograph is concerned with the approximately twenty species of "Old World" or "True" sparrows which make up the genus *Passer*. Each species is described in a separate chapter; the only exception being five species of Afrotropical grey-headed sparrows which are covered in separate sections of a single chapter. The accounts range in length from three pages (*Passer suahelicus*) to almost 60 pages (*Passer domesticus*). With a few minor exceptions, the species account chapters follow a standard format made up of sections on nomenclature, description, biometrics, distribution, habitat, behaviour, breeding biology, survival, moult, voice, and food.

The nomenclature sections list and summarize the various scientific names used in the current literature; the description sections describe the physical appearance of each subspecies; the biometric sections give body measurements, often in the form of tables; distribution sections give the range of each subspecies and usually include a range map or maps; the habitat sections describe the species habitat; the breeding biology sections supply a description of the breeding behaviour of the species; the survival sections provide lifespan data, although data are only available for five species; the moult sections chronicle the species' moult; the voice sections furnish transcriptions of the vocalizations of the species; and the food sections describe the food eaten by the species. The information contained in the sections ranges from very extensive to non-existent.

After 16 chapters of species and subspecies accounts there is a chapter on the characteristics of the genus as a whole, the interactions between the members of the genus, and information on dispersal, colonization, and range extensions. The next chapter presents the origins and evolution of the genus. The final chapter describes the systematic positioning of the genus *Passer*, focusing on the relationship of *Passer* to other genera and on the relationships of members of the *Passer* genus to each other. Summers-Smith concludes that *Passer* is one of the three genera which make up the Passeridae family.

The book has two appendices; one is an alphabetical key to the past and present names of *Passer* sparrows and the other is a gazetteer. There are 21 pages of references, arranged alphabetically by author, and a six-page index. Eight pages of full colour plates by Robert Gillmor illustrate all the species. Scattered throughout the text are black-and-white illustrations, also by Robert Gillmor, and 50 tables and 114 figures showing range maps, breeding seasons, bill colour scores, biometric data, moulting sequences, population densities, and other such information. The final table shows Summers-Smith's classification of *Passer* at the subgenus, superspecies, species, semi-species, and subspecies level.

Summers-Smith has 20 species of *Passer*, and although English names differ, his species classification is fairly close to some of the commonly used world check lists. For example, Clements (1974) has 19 species; Howard and Moore (1984) have 21 species; and Gruson (1976) has 19 species. Summers-Smith differs from Clements by "splitting" *Passer iagoensis* from *Passer motitensis*. He differs from Howard and Moore by splitting *Passer diffusus* from *Passer griseus;* splitting *Passer iagoensis* from *Passer motitensis*; "lumping" *Auripasser luteus* and *Auripasser euchlorus* into *Passer luteus*; and by lumping both *Passer insularis* and *Passer rufocinctus* with *Passer motitensis*. Summers-Smith differs from Gruson by lumping *Passer luteus* and *Passer euchlorus* into *Passer luteus*; by splitting *Passer diffusus* from *Passer griseus*; and by splitting *Passer motitensis* from *Passer iagoensis*.

On the whole, the book is very good, although it does have a few, relatively minor, faults. The author presents the argument that *Passer montanus* should be referred to as the "Eurasian Tree Sparrow" (page 13) yet he uses the less clear "Tree Sparrow" throughout the remainder of the book. The nomenclature sections of each chapter could have been improved had Summers-Smith briefly detailed where and how he differs from the nomenclature presented; for example, the nomenclature section for *Passer diffusus* lists four subspecies (page 38) yet the account only considers three of these.

Most account are complete and logically presented. However the account for *Passer motitensis* is somewhat disjointed. This is the only account where "populations" are written up as if they were species. The material accompanying the nomenclature section for the species is not clear and the range map not only shows the range of *Passer iagoensis* (which is described in another chapter) but neither the range map nor the text indicate that seven subspecies are going to be considered as five populations; nor is there any indication that each of these populations has its own English name. The author does not describe why it is only populations of *Passer motitensis* that have English names nor does he provide description sections for each of them.

Other criticisms include a range map with no key as to what the various hatch marks represent (page 171) and range maps which are labeled for a species but in fact only pertain to a particular subspecies (for example pages 183 and 185 which are labeled for the Dead Sea Sparrow, but only show the range of the nominate race). For the subspecies *nigricans* of *Passer ammodendri* there is a range map and a written description of the range but no description of the bird's appearance. Typographical errors also occasionally appear.

In conclusion, although the book has some faults, these are more annoying than serious and cause relatively little confusion. The colour plates are excellent, although the black-and-white illustrations have a washed out appearance and really don't contribute much except to provide relief from the printed word.

This book is recommended for all those with a serious interest in birds. This reviewer hopes that *The Sparrows* will not be given the same disdain which is so often given to the House Sparrow; especially as the book provides an opportunity for readers to acquire an appreciation and better understanding of the *Passer* genus, the "meanest of the feathered race."

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STEPHEN GAWN

6 7-D Bowhill Avenue, Nepean, Ontario K2E 6S8.

The Common Loon: Spirit of Northern Lakes

By Judith W. McIntyre. 1988. Fitzhenry & Whiteside, Toronto. xii + 228 pp., illus. + 1 record. $29.95.

A recent proliferation of books on loons in particular and diving birds in general may call into question the need for yet another. However, recent works on loons can be divided into "popular" accounts and collections of research papers presented at conferences. A comprehensive treatment synthesizing the many research papers that have appeared on Common Loon biology in recent years has become increasingly desirable, and this is it. Readers of Judith McIntyre's previous research papers would expect her to produce a comprehensive and authoritative treatise on this species, while those who have heard her enthusiastic lectures would expect a book that is far from tedious. Neither expectation is wrong.

A foreword by William H. Marshall, co-author of the previously most comprehensive mongraph on this species, opens the book. In her preface, McIntyre comments that facts are not and never will be "all in," but her lengthy acknowledgments indicate that this work is based not only on her own extensive research in Minnesota, New York, Saskatchewan, and elsewhere, but also on both published and unpublished data of many other researchers. The text begins with an unnumbered chapter on "myths, legends and beliefs", followed by ten chapters on loon biology, and two closing chapters on threats to loons and loon conservation. The first three numbered chapters follow the annual cycle of loons from arrival and territorial behaviour through courtship, nesting and hatching to care and development of young. Chapter 4 and Appendix 3 cover parasites and diseases, while Chapter 4 also discusses populations, productivity, and survival rates. Chapters 5 through 7 cover behaviour, including maintenance, feeding, social interactions, and visual and vocal communications. Chapter 8 considers the evolution and classification of loons, both within the family and in relation to other birds. Tables offer at-a-glance comparisons between loons and *Hesperornis* and between loons and grebes. This chapter also includes a table of names of loons in general in several European languages, including both European and North American names in both English and French. This table continues with names for the Common Loon in 15 European languages and nine North American native languages. Anatomy, plumages and moulting are covered in Chapter 9, while Chapter 10 considers breeding and winter distribution and migratory routes, including a plea for more information on poorly understood movements of juveniles. The second last chapter outlines human impacts on loons, ranging from recreational and developmental pressures, direct killing and indirect effects, to the influence of various pollutants. Activities of scientists, government agencies and amateur-dominated loon organizations to help conserve loons are highlighted in Chapter 12. The first two appendices consist of conversions between metric and "U.S." units and scientific names of taxa mentioned in the text. A 13-page list of references and an index close the book.

To be of greatest value to scientists, a book of this sort should be a thorough and accurate compilation of information to date, clearly identify topics requiring further or ongoing research, and serve as *the* key source of previous publications to which the reader may turn for more details on a specific topic. McIntyre has done an excellent job on these objectives. She has not shied away from speculation, especially to promote further research. But known facts are clearly separated from speculations.

Factual errors and omissions are few. However, the estimated populations attributed to "Ashender" (i.e. Ashenden) for Ontario and to "McNicoll" (i.e. McNicholl) for Quebec and Canada, presented in Table 10-1 and page 154, were highly speculative "guestimates" made in answer to questions at a conference and not in the papers cited. Similarly, the citation to the 1985 supplement to the checklist of the American Ornithologists' Union is inappropriate because this does not include a discussion of subspecies of Common Loons. Although much of the area visited by Raine was in the Northwest Territories when he wrote his book, he did not visit any area now in the territories, and the nest data attributed to him in the first section of Table 2-1 would now be correctly placed in one of the prairie provinces. Canadian content is high, but data on Ontario nests from the book on Ontario breeding non-passerine birds by Peck and James (1983) would have provided useful additions to the tables on nests and clutch sizes in Chapter 2. McIntyre has included most of the published notes on summer flocking, but has missed at least a couple, of which A.L. Rand's 1948 contribution (*Canadian Field-Naturalist* 62: 42–43) would have been especially appropriate as drawing attention to this phenomenon. The section on acid precipitation effects is thorough, but readers with particular interest in this topic should also consult the more recent papers by Alvo et al. (*Canadian Journal of Zoology* 66: 746–752, 1988) and by Parker (*Canadian Journal of Zoology* 66: 804–810, 1988).

Unfortunately, proof-reading of references was not thorough. There are a number of misspellings

and a large number of references cited are not found in the list at the end of the book or are wrongly cited in it.

Scientific accuracy and thoroughness does not preclude this book from being enjoyable to read for casual readers. Technical details tend to be relegated to tables that can be ignored by readers not interested in the detail and also provide the details at a glance to those who wish to study them. Line drawings by Anne Olson are spread throughout and a group of colour photographs grace ten plates in the centre of the book. Even some of the graphs are illustrated with appropriate loon figures. Accounts of displays are tied not only to illustrations of the behaviour discussed, but also to their accompanying sounds on a recording inserted into the back of the book *and* to sonograms of these sounds. McIntyre manages to convey scientific information in evocative, often humorous prose. We learn that loons weigh "less than a stick of butter" when they hatch and "pop up like corks" when they attempt to dive. McIntyre even coins two new words (loonlings and loonmania) with obvious meanings.

In spite of its plethora of proof-reading errors, Judy McIntyre's book is both authoritative and a pleasure to read. Without doubt, this is the best book to date on Common Loons. It will contribute substantially to outdating itself by stimulating still more research into the author's favourite subject.

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M 1X4

Birds and Berries

By Barbara and David Snow. 1988. Buteo Books, Vermilion, Soiuth Dakota. 268 pp., illus. U.S. $37.50.

The authors studied the feeding habits of fruit-eating passerines in an area of southern England for five years; they also brought their considerable background of research in Europe, the Americas and Trinidad to bear on their conclusions. The bibliography shows there are many publications dealing with specific species of birds or fruits, but this study was wider in its scope, describing detailed observations of 16 species of bird feeding on 36 species of fruit.

The three major sections describing the fruits, the birds and interpretation of findings are subdivided into short sections on each fruit and bird which were kept under observation, together with relevant tables of data such as feeding frequency and the number of visits to a plant. The ecological importance of fruit foraging by birds is discussed and some interesting conclusions about evolutionary strategies by plants for seed dispersal are drawn.

Appendices include analyses of the fruits, such as chemical breakdown, weight, nutritive and bulk yields, and dimensions — an important factor when related to gape size of a bird.

The fruit eating birds in the study area are mainly thrushes and finches. A factor continually occurring throughout the book is the effective control over some food sources by Mistle thrushes (*Turdus viscivorus*). Individual Mistle thrushes will defend a holly tree or mistletoe against other foragers, but will eat other available fruits in early winter. If they are successful in retaining "their" fruit, they will eat it in late spring when other fruits are scarce. In hard winters, though, their defence can be overwhelmed by a bird army arriving and stripping the hoarded fruit. Hence, a tree or bush with berries after November is most likely one defended by a Mistle thrush.

Just as some questions are answered by the study, more are raised. For instance, a number of the fruits are poisonous to mammals, but in most cases the poisons have not been identified nor has their location within the berry; it is not always known how birds avoid the poisonous part of a fruit or, if ingested, what mechanisms they have to neutralize the poison.

It is interesting that overlapping ripening times of different fruits provide a succession of food throughout the year, while the ubiquitous holly retains its fruit for the longest period (6 months) and is a source of food for almost all fruit eating birds.

The illustrations would have been more useful if they had been captioned.

The authors have made new scientific contributions to research in publishing their results and conclusions, and they offer some interesting theories about the coevolution of birds and plants. This will be an invaluable resource text in the libraries of Wildlife and Botany researchers and students.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

Recent Advances in the Study of Bats

Edited by M. Brock Fenton, Paul Racey, and Jeremy M. V. Rayner. 1987. Cambridge University Press, New York. xii + 470 pp. U.S. $69.50.

This book contains a collection of papers presented at the joint meeting of the Seventh International Bat Research Conference and the Third European Bat Research Symposium held at the University of Aberdeen in August 1985. The contributions are grouped under three main headings corresponding to the symposia of the meeting: Flight, Echolocation and Social and Reproductive Biology. Individual contributions in the section on flight, seven in number, deal with the origin of flight, the mechanics of flight, form and function of wings, and physiological aspects of flight. The symposium on echolocation comprises eight presentations on subjects ranging from discrimination and processing of echolocation calls to echoes of fluttering insects and the interaction of bats and moths. The final section has eight contributions reporting on major advances in the social and reproductive biology of bats. A wide range of topics is covered, such as genetic structure of bat social groups, altruism and cooperation in bats, prolonged storage of spermatozoa in hibernating bats, energetics of pregnancy and lactation, growth and energetics of suckling bats, and endocrinological aspects of reproduction.

In all, this book contains much new information from a number of the world's foremost chiroptologists. It will be most useful to biologists working on bats, as well as to those with a keen interest in this group of mammals. Because of its specialized topics and technical presentation it would not appeal to the general naturalist and the price will deter students from acquiring it.

C. G. VAN ZYLL DE JONG

Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

On the Track of Ice Age Mammals

By Antony J. Sutcliffe. 1986. Harvard University Press. Cambridge, Massachusetts. 224 pp., illus. Cloth U.S. $25; paper U.S. $12.95.

This book is an example of popular science at its very best. It is authoritative (the author is curator of Pleistocene Mammals in the British Museum of Natural History), well written, and copiously illustrated. It contains an astonishing amount of material.

There is much on the mammals themselves, of course, the mammoths, mastodons, woolly rhinos, sabretooths, and many, many more; on what species lived in different regions at different times; on their ecology; and on how they migrated in response to changing climates. There is a wealth of other topics besides: the cause of glaciations; the various ways in which animals become fossilized; how fossils are dated; what can be inferred when fossils are found to have been displaced or damaged; the various strategies of fossil-hunting; what can be learned about ice-age life from the drawings on cave walls made by contemporary human cave-dwellers; the histories of paleontological exploration at such famous sites as the asphalt pits of Rancho La Brea in Los Angeles, and of Olduvai Gorge in Tanzania (to name only two). The book will be an eye-opener to people who regarded paleontology as a narrow, dusty subject of interest only to museum specialists.

The diversity of the illustrations (all of them excellent) gives some idea of the diversity of the subject matter. There are maps, diagrams and drawings; there are photographs of fossils, of museum reconstructions of animals, of fossil sites, and of paleontological work-in-progress; there are artist's reconstructions, in colour, of typical ice-age scenes in different parts of the world. each teeming with contemporary animals; there are reproductions of paleolithic cave art; there are illustrations of paleontological history, for example, a photo of a painting showing the excavation of a mastodon fossil in New York State in 1799. There is even a relevant cartoon joke from "Punch."

Canadians will be glad to find that Beringia (the unglaciated region around and including the Bering landbridge of ice age times) has its fair share of attention. Surprisingly, Sutcliffe appears to accept the hypothesis that, even when the climate was at its most severe, the region was covered by highly productive vegetation, the so-called "mammoth steppe" or "steppe-tundra". He makes no mention of the contrary hypothesis, that fodder for mammoths was sufficient for only a few, small herds, and that their fossils are numerous only because they represent the accumulated remains of many millennia.

The only unsatisfactory chapter in the book is the last, on the great wave of extinctions that mark the Pleistocene/Holocene transition. Rather than conceding that its cause is one of the great unsolved problems of modern paleontology, Sutcliffe puts forward the idea that the causes "differed from one instance to another," or in other words, that each extinction is explicable by a just-so story unique to

the species concerned. He would even have us believe that mammoths became extinct because geographically separate populations died off, each for a different reason, more or less simultaneously. He expresses no surprise that a score or more of unrelated extinctions all happened within a short interval of one or two millennia. He dismisses the notion that any (or all) extinctions could have resulted from some catastrophe, seemingly on the ground that the only imaginable catastrophe is the Biblical Deluge, and that was demonstrably a non-event.

My only other criticism of this interesting, readable book is that (like most other popular science books) it lacks references. Books like this one are not only for amateur scientists. As well, they are useful to, and enjoyed by, professional scientists in related fields, for whom the absence of references to the original literature is tormenting.

E. C. PIELOU

RR1, Denman Island, British Columbia V0R 1T0

La biologie du Suceur cuivré, *Moxostoma hubbsi*, une espèce rare et endémique à la région de Montréal, Québec, Canada

Par Jean-René Mongeau, Pierre Dumont, et Louise Cloutier. 1986. Rapport technique du Ministère du Loisir, de la Chasse et de la Pêche no. 06-39, Gouvernement du Québec, Montréal. XXV + 137 pp., 15 figs. Gratuit.

Ce rapport technique comporte des sommaires en français et en anglais (la qualité de ce dernier laisse à désirer), suivi d'une introduction et de cinq chapitres traitant respectivement du statut taxonomique du Suceur cuivré, de la répartition de l'espèce, de sa biologie, de l'évaluation de l'importance biologique et économique de l'espèce, de son statut écologique actuel, et finalement, de son avenir. Cette étude avait pour objectif de rassembler toute l'information disponible sur la biologie de cette espèce endémique à la partie sud-ouest du Québec, et ce, afin de déterminer son statut pour les fins du CSEMDC (Comité sur le statut des espèces menacées d'extinction au Canada). Les auteurs considèrent le Suceur cuivré comme étant une espèce menacée et indiquent que sa survie est directement liée aux efforts qui seront déployés pour contrer l'érosion, l'irrégularité des débits, et la pollution sous toutes ses formes.

Mongeau et ses collaborateurs ont effectué un travail remarquable en étudiant 156 des 248 spécimens de Suceur cuivré officiellement recensés depuis sa découverte en 1942 jusqu'à 1985 inclusivement. Ils ont même documenté la présence de cinq spécimens de *Moxostoma hubbsi* en provenance de deux sites archéologiques, le premier datant de la période pré-1534 et le second entre 1802 et 1838. De plus, ils comparent la biologie du Suceur cuivré à celles des quatre autres espèces de suceurs qui lui sont sympatriques: le Suceur ballot, *Moxostoma carinatum*; le Suceur blanc, *M. anisurum*; le Suceur jaune, *M. valenciennesi*; et le Suceur rouge, *M. macrolepidotum*. Pour ce faire, ils s'appuient sur les données trouvées dans la littérature scientifique et sur leurs propres observations. Les aspects suivants de la biologie sont traités: croissance, longévité, diète, âge à la maturité sexuelle, période de fraye et température à laquelle elle a lieu, fécondité, habitat, espèces de poissons coexistant avec le Suceur cuivré et leur abondance relative. Ils soulignent également les lacunes quant à nos connaissances de la biologie du Suceur cuivré, comme par exemple, certaines caractéristiques des frayères. La bibliographie exhaustive comprend 103 titres publiés entre 1844 et 1986 inclusivement. Depuis la parution de ce rapport technique, une publication d'intérêt par Mongeau et ses collaborateurs s'est ajoutée. La référence à cette publication figure à la fin de ce compte-rendu.

Dans le chapitre traitant du statut taxonomique, Mongeau *et al.* dresse l'historique de la découverte de l'espèce. Ils mentionnent que Vianney Legendre, l'auteur de la description originale du Suceur cuivré, et Vadim D. Vladykov, qui oeuvraient indépendamment, en ont faites la découverte presque simultanément et que pour des raisons inconnues, feu le Prof. Vladykov ne publia jamais le résultat de sa découverte. Peu de temps avant sa mort en janvier 1986, Vladykov léguait toutes ses archives au Musée canadien de la nature. Parmi celles-ci, j'ai trouvé deux versions d'un manuscrit inédit du Prof. Vladykoiv relatant cette découverte. Il est intéressant de noter que Vladykov avait en sa possession deux spécimens de *Moxostoma hubbsi*; l'un provenait du fleuve St-Laurent au niveau de Lavaltrie et l'autre, du côté sud du lac St-Pierre entre les rivières St-François et Nicolet, et non pas comme le rapportait Legendre (1964: 176) dans la rivière Yamaska à Saint-Hyacinthe. Je n'ai malheureusement pas encore pu retrouver ces spécimens.

La qualité des figures est de passable à bonne. Une clé illustrée permettant l'identification des spécimens de plus de 25 cm des cinq espèces de *Moxostoma* (suceurs) et des deux espèces de *Catostomus* (meuniers) du Québec est fournie. Des

cartes de répartition très détaillées sont présentées pour les suceurs. Les lecteurs doivent cependant surveiller la non-correspondance entre certaines valeurs dans les tableaux, les figures et le texte, notamment les tableaux 4 et 23, et la figure 6. Au tableau 7, il y a répétition des données pour les suceurs ballot et jaune.

Nonobstant plusieurs imperfections d'ordre mineur, je recommande cet ouvrage à toute personne s'intéressant aux espèces menacées en général et sur les catostomidés en particulier.

Litérature Citée

Legendre, V. 1964. Les vivants au Québec: les découvertes récentes. Ministère du Tourisme, de la Chasse et de la Pêche, Service de la Faune du Québec, Rapport no. 3: 170–186.

Mongeau, J.-R., P. Dumont, L. Cloutier, et **A.-M. Clément.** 1988. Le statut du Suceur cuivré, *Moxostoma hubbsi,* au Canada. Canadian Field–Naturalist 102(1): 132–139.

CLAUDE B. RENAUD

Section d'ichtyologie, Musée canadien de la nature, Ottawa, Ontario K1P 6P4

Butterflies of the World

By Rod and Ken Preston-Mafham. 1988. Facts on File, New York. 192 pp., illus. $30.95.

Books on butterflies are not a rare item these days. But a book for the serious amateur naturalist who wants something at once informative yet not too technical, is hard to find. Part of the answer to that dilemna could well be *Butterlies of the World.*

At first glance, especially when browsing the excellent colour photographs, it may seem to be a book for the select few who are able to achieve a butterfly-watching trip to the tropical areas of the world. But a closer look at even the table of contents, soon demonstrates that this book has a great deal to offer to most butterfly enthusiasts.

Butterflies of the World, one in the series *Animals of the World,* provides a very readable and complete, nontechnical introduction to the biology and ecology of butterflies. In the introduction to the book the authors state their intended purpose for writing this volume: to summarize for the reader some of the "voluminous" scientific information now available on butterflies, and to add to that growing body of knowledge, detail from their personal observations.

A summary of current information is achieved in such chapters as: "Structure of the Adult Butterfly", "The Life-cycle of the Butterfly", and two complete chapters on "Adult Behaviour". The first two-thirds of the book contains a very complete review of the basic biology of butterflies without becoming caught up in the technical language of research.

The information contained in the last three chapters of the book is often not easily accessed by the non-professional reader. Here the authors discuss what is becoming a focus of many butterfly studies: the ecology and future of this group of insects, and the part that man plays in that future.

That many species of butterflies are in jeopardy because of the destruction of their habitat, especially in the tropical forests of the world, is a well-known fact. This book says some things that will cause the reader to think hard about the decrease in world species and the individual's responsibility for conservation.

One of the best things about picking up this book, is the excellent quality of the many photographs with which the book is illustrated. Even more noteworthy is the fact that the photographs were all taken by the authors, in the natural habitat of each species, without resorting to the trickery of capture and all that goes with contrived photography. A bonus which comes with the book is the suggestions the authors make for this kind of photography. The fine picture quality makes up for the fact that the majority of species illustrated are tropical; they are however, well-chosen to illustrate concepts covered in the text.

Butterflies of the World includes a very limited glossary of only the more technical words used in the book. In the main the text is not difficult, therefore the glossary does well enough for this volume. A well devised index, where main entries are highlighted, enhances the usefulness of the book. Ease in information finding is further facilitated by the use of cross referencing within the text itself; the reader is referred to more detailed accounts found in other parts of the book.

Though the authors defend their use of moving from the third person to the first within the text, I for one find this somewhat annoying. The technique used is to summarize in the third person the information on scientific research, and to move into the first person when relating personal experience and observation. This might have worked better for the authors if they had separated the two techniques in some way, perhaps even by paragraph. For the reader it becomes a distraction of no little account, which is unfortunate, for the personal observations include some of the most interesting passages in the book.

Even in this book mistakes have crept in, none of which detract measureably from its fine points. On pages 26 and 27, for instance, the captions of two

photographs have been interchanged; on page 45 the caption is missing entirely.

If the achievement of the intended aims of a book were the only criteria for its value, then this book would certainly qualify. For the naturalist who wants at hand a summary of current knowledge about butterflies, at once complete and nontechnical, the book does very well. Add to this its attractiveness and the wealth of personal field observation, and *Butterflies of the World* becomes a book easy to recommend.

HELEN KNIGHT

Box 131, Clearwater, British Columbia V0E 1N0

The Evolution of Vertebrate Design

By Leonard B. Radinsky. 1987. University of Chicago Press, Chicago. xi + 188 pp., illus. Cloth U.S. $35; paper U.S. $12.95.

This is based on the author's course on vertebrate morphology, paleontology, and evolution for undergraduates not majoring in biology. It was edited and completed after his death by Sharon B. Emerson. One of us (RvdH) is a high-school student with no particular interest in paleontology, the other (FWS) a vertebrate zoologist who has not kept up with the paleontological literature in a decade since graduate school, but our responses to it were quite similar.

The title may lead one to expect a book about evolutionary theory, but one finds a manual of evolutionary history, concerned mainly with bony and cartilaginous fishes and reptiles. The discussion of adaptations is fascinating and astonishing, the text is excellently worded, concise and comprehensible. An informative introduction presents the basic ideas of adaptation and animal design, and reviews the elements of evolutionary theory.

There are four chapters devoted to fishes, two on amphibians, five about reptiles and their different designs for marine life, flight, and land, and three chapters about mammals. These chapters provide a basic review of each animal's background, when it originated, and what it looked like, emphasizing the size and number of teeth, the neck and head size, the length and use of the appendages, and the length and size of the body. The illustrations are diagramatic. Some, such as a polished metal ceratopsian on the front cover, are drawn to look like mechanical models, but the most successful are body outlines with black bone silhouettes of the skeleton that convey the excitement of the shapes of real bones.

The age of events is measured by a year that represents the age of the Earth, rather than by geological periods. The evolution of vertebrate design begins in late November, and most of the action is crowded into December. The apparent youthfulness of mammals (a Christmas present) and people (a New Year's Eve noisemaker) on this scale is tempered by the debut of armoured invertebrates on or about Armistice Day.

For RvdH this was unknown ground. She found that Radinsky drew parallels from her world that helped her understand unfamiliar scientific terms and past worlds, but that the introduction did not prepare her for such terms as phylogeny and dichotomy. She liked the beginning of the book, thinking that she could really understand the material, but was somewhat cast adrift among the sketchy descriptions of unfamiliar animals. She would have liked more about how information can be read from the fossils, a few more pages about people, less on fishes, and more on mammals and birds.

For FWS this was familiar territory, and the book seemed, in text and illustrations, to be a simplified version of A. S. Romer's *The Vertebrate Body*. He was somewhat bothered that it was assumed without saying that orders of modern amphibians are related, by the many unlabelled branches on phylogenetic trees, that animals are measured in feet, and by the description of the brain of the first vertebrate as "a great nervous center".

There are few obvious errors. For heterostracans "3-6 feet in length" is considered "a gigantic size for an animal making a living as a bottom dwelling detritus feeder", which must make sturgeons feel uncomfortably over-sized. Aardvarks have "lost all vestiges of teeth" on page 157, but are more correctly "peg-toothed" on page 164. As in *The Vertebrate Body*, birds are slighted, with only seven pages of text, tucked into a chapter on reptilian flight. The six lines on the avian skull do not mention the kinetic (hinged) upper jaw which is the basis of feeding for many birds.

This is an excellent first introduction to vertebrate paleontology and diversity, and would be especially appropriate for high-school students interested in these fields.

FREDERICK W. SCHUELER

Herpetology Section, Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

ROSE-MARIE VAN DER HAM

RR 3, North Augusta, Ontario K0G 1R0

Wildlife Ratio Tagging: Equipment, Field Techniques, and Data Analysis

By Robert Kenward. 1987. Academic Press, New York. x + 222 pp., illus. U.S. $29.50.

In the last two decades radio-tracking has become an important wildlife technique allowing researchers to locate an individual animal at any time. It has provided useful information on many elusive and secretive species. Robert Kenward has a vast experience in radio-tracking as this book shows. This is a clearly written book, which effectively tells the basics of animal radio-tracking. In addition, the book offers much practical advice which will be useful to everyone planning or presently involved in radio-tracking.

The book starts with suggestions on what projects can benefit from radio-tracking and which study animals to select. This is a candidly written chapter, but at places appears negative. A brief description of studies that achieved their aims only because of radio-tagging (e.g., Marquiss and Newton 1981), could have been presented. Kenward also points out that patience and time are needed to develop satisfactory field techniques for radio-tracking projects. He warns that it is "certainly no technique to grasp at in the last year of a tricky doctoral thesis".

The book offers a fairly good discussion on various radio-tracking equipment and transmitters. The suitability of each different kind of equipment is pointed out. This may help you to state your precise requirements to a professional supplier when placing an order. A list of commercial suppliers of radio-tracking equipment and transmitters is furnished. Additional addresses can be found in Fuller (1987). The author gives details on radio transmitter building and assembly, although if enough funds are available, it is better to rely on the skills of a commercial manufacturer.

The techniques of tag attachment are elaborately dealt in a separate chapter, although some parts of this chapter are repeated from a previous chapter on basic equipment (Chapter 2. Part D — mounting techniques). The book has a clear introduction of radio tracking in field, both from mobile and fixed stations. Contrary to the author's recommendation,however, thirty radio locations may not be enough to correctly estimate home ranges (see Bekoff and Mech 1984).

The last chapter is on data analysis. This chapter breaks from the excellence of the book shown in previous chapters. Detailed examples of each technique discussed and a comparison of different techniques so as to point out their shortcomings and strengths would have been useful. Many species are radio-tagged to study utilization of their habitat, but the data analysis chapter is devoid of techniques to analyze such data (e.g., Alldredge and Ratti 1986). Moreover, the Fourier Transform method (Anderson 1982) of estimating home ranges is also missing.

The literature cited is neither particularly up to date nor complete. Some data analysis BASIC programs are presented in an appendix. There are more than sixty illustrations and about seventeen plates in this book. All of them assist the text effectively.

I found this book to be easy reading and very informative. I recommend this book highly, a must for someone planning to start a radio-tracking project.

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NAVJOT S. SODHI

Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Animal Navigation

By Talbot H. Waterman. 1989. viii + 243 pp., illus. $49.50.

Long one of the chief areas of interest in the study of animal behaviour, navigation is given a comprehensive and stimulating presentation in this book. The framework is set in the Introduction by distinguishing types of navigation and associated activities. (The readership is perhaps parochially restricted in a point regarding "the temperate zones where most of us live".) The first two chapters present excellent overviews of navigation by flying and swimming animals, including the relation of navigation to migration. The intriguing ability of Pacific islanders to traverse long distances, and the methods used, are examined in the third chapter, while the next

chapter provides a superb synthesis of mechanisms permitting spatial orientation and course keeping, such as righting reflexes and inertial guidance. Three chapters focus on sensory modalities mediating navigation via visual compasses to sun, stars, moon, and polarized light, mechanoreception (including lateral line systems and echolocation), chemo- and thermo-reception, and electrical and magnetic cues. Controversial issues, such as the role of odours in pigeon homing and sensitivity to magnetic fields by humans, receive appropriately cautious evaluation. Perception of space and time is considered in two further chapters, with good discussion of piloting, animal maps, exploration, and rhythms of varying periodicities. A final chapter deals with the evolutionary question of why animals migrate in terms of adaptation, genetics, and phylogeny. Amid the speculation rampant in functional biology these days, the treatment is gratifyingly succinct and sensible.

The author is well known for his contributions in sensory and behavioural biology. The scope of his interests is reflected in the broad coverage which he provides including details on such related issues as sensory and physiological mechanisms, communication, learning, and foraging patterns. The style is flowing, with technical terms such as "taxis" and "kinesis" omitted, and references limited to a list of selected readings preceding the index. There is a healthy emphasis on not only what is known but also what remains unclear, such as the failure of some species to migrate appropriately in some portions of their range, and the continuing problems associated with the cues actually used by pigeons in homing. Indeed, the recent refutation of the hypothesis, cited in this book and widely elsewhere, that the pattern of migration by Green Turtles in the mid-Atlantic Ocean is due to continental drift, indicates how much our understanding can be expected to change in the future. In keeping with the format of the publisher, the lavish composition is rich with coloured illustrations and wide margins, but nonetheless occasionally flawed, most graphically with a laterally inverted Ptolmaic map. There are currently a lot of books available which deal with animal navigation for different levels of readership, but Waterman's certainly holds the lead for an attractive, non-technical, yet competent presentation of the topic.

PATRICK COLGAN

Biology Department, Queen's University, Kingston, Ontario K7L 3N6

BOTANY

Plants for Beekeeping in Canada and the Northern USA

By Jane Ramsay. 1987. Burlington Press (distributed by Plants for Beekeeping, Cambridge, England. 198 pp., illus.

This book is an encyclopedic reference manual to the honey plants which are known to occur in areas of interest to beekeepers in the region indicated by the books title. It is thoroughly researched and contains the most comprehensive bibliography ever assembled in North America on the subject. One of its most important features is the method employed by the author in organizing the information. Plants are categorized into their life-histories such as annuals and biennials; perennials; trees and shrubs. The introduction outlines the overall thrust of the work and clearly points out the purpose of the authors intent. It is intended to be a practical handbook for beekeepers and to show them the great diversity of potential species of vascular plants available to honeybees. Scientific and local common names are given and properly indexed. In addition, nineteen tables are included showing data such as pesticides harmful to honeybees, honey production statistics, and crops visited by honeybees. A very useful part of the work gives the phenological information of the various species treated. These data should aid beekeepers in management of their apiaries and help them in the more efficient use of their beeyards.

The final pages of the book give maps of plant hardiness zones of Canada which may prove to be useful to beekeepers who wish to grow plants for augmenting their honey production or to those who want to produce unifloral exotic honeys.

My main criticism of this book is that it tries to cover too many topics. As a result of this minor flaw, several of the chapters have little to do with plants for beekeeping. For instance, the sections on pesticides, although important to hive management, are mainly concerned with crop plants, nursery, and forestry operations. Pesticides about the home garden probably have a minimal effect on commercial beekeeping operations. A secondary minor source of criticism is that too many plants are included in the main body of the work. Many of the taxa do not occur in enough frequency or abundance to contribute significantly to honey production.

Overall, this book should prove to be a useful addition to the bookshelf or library of all persons interested in beekeeping and other aspects of one's natural surroundings. The author should be complimented for undertaking such a large task. An interesting aspect about this book is the obvious care and attention given to accumulating all of the current relevant material. This shows a dedication on the part of the author towards honeybees, beekeepers, apiculture in general, and agriculture in particular, since without the help of these small animals much of our present horticultural and forage crop production would "bee" impossible.

As a botanist it would be remise of me not to point out that there are some minor problems in the work with regard to the scientific nomenclature. The author has dealt with this issue by including synonomy within the main part of the text. Cleverly, she has solved this problem by following standard botanical texts such as Gray's Manual of Botany for much of the native and introduced flora and Hortus Third for the cultivated species.

C. W. CROMPTON

Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario K1A 0C6

Mineral Nutrition of Higher Plants

By Horst Marschner. 1986. Academics Press (distriburted by Harcourt Brace Jovanovich, Don Mills, Ontario). xii + 674 pp., illus. $138.75.

The textbook, *Mineral Nutrition of Higher Plants*, provides a very comprehensive and contemporary coverage of the topic of mineral nutrition. This is an extremely broad area of current scientific endeavor, including the absorption of essential nutrients by roots of higher plants, their translocation within the plant body, and their assimilation and ultimate conversion to harvestable crop products. Marschner's treatment of these topics and related ones of plant/soil interactions is at an appropriate level for the graduate student and research worker rather than the beginning student.

The strengths of Marschner's approach to the mineral nutrition of higher plants lie in his detailed coverage of the primary literature. The book is strongest in those sections dealing with yield responses (Chapters 5 and 6), functions of the elements (Chapterts 8 to 12 inclusive) and soil-plant relations (Chapters 13 to 16 inclusive). The book is less adequate in Chapters 2 and 3 which discuss the topics of membrane transport and the biochemistry of membrane function.

Because of its extensive coverage of most topics, the textbook will serve as an excellent resource book. However, in my opinion, the author is too frequently encyclopedic in his treatment of topics, tending to faithfully report the views of the various advocates in contentious areas rather than evaluate the evidence being advanced. Herein lies the book's only significant weakness; it fails to provide sufficient guidance to the reader. However, since the book is designed for the advanced student it may be argued that the reader can make up his/her own mind in these areas.

A minor frustration for me was the author's repeated reference to negative water potentials or osmotic potentials as being higher than more positive potentials when, of course, they are actually lower. This incorrect use of negative numbers is an unnecessary source of confusion to the uninitiated. In fact, as a teacher of plant physiology I have long battled to eradicate this problem among my undergraduate students. Notwithstanding these criticisms, the book is a welcome update of some earlier classics in mineral nutrition. The book will almost certainly prove to be a valuable and much used source book for those involved in studies of mineral nutrition.

A. D. M. GLASS

Botany Department, University of British Columbia, Vancouver, British Columbia V6T 1W5

Weeds

By Walter Conrad Muenscher. Second Edition 1955. Reissued 1987 with a new foreword and appendices by Peter A. Hyypie. Cornell University Press, Ithaca, N.Y. 586 pp. illus. U.S. $16.95.

There is a continuing need for a good, comprehensive book on weeds of North America. Evidence for this is the appearance in paperback of a book first published in 1935, updated in 1955, and reissued in 1980 and 1987 with a new foreword (1½ pages) and three appendices. Dr. Peter Hyypio states that this publication "continues to be an outstanding book on the identification and control of weeds. It is still the most comprehensive survey of the common weeds of the northern United

States and Canada". In general Hyypio's latter claim is true but there are serious deficiencies in this book for Canadians who wish to identify and control the weeds on their properties.

First, the good points. A total of 571 weeds are described, with approximately two brief paragraphs and one black-and-white drawing each. The name, life-cycle, geographical distribution in North America, origin, time of flowering and a brief description are given for each species. Muenscher does not give detailed recommendations for control but he does provide a paragraph or two about 26 different means of control in an introductory chapter and the appropriate methods for each species are listed (e.g. to control Tall Buttercup, *Ranunculus acris,* we are referred to method 21 which tells us to improve the drainage). Many of the species described by Muenscher are still very important weeds and the biological information provided on them has not gone out-of-date. Muenscher included a detailed key to all of the species and he has also incorporated smaller keys to difficult genera. One of the most interesting and important sections of this book, running from pages 3 to 62, describes the characters and habits of weeds, their means of reproduction and dissemination, and also includes details of the origin of weeds, poisonous weeds, losses and benefits caused by weeds, weeds of specific habitats and weeds as medicinal plants. Much interesting data from a variety of sources are presented in tabular form. References for this information, most of it pre-1935 and often unavailable in literature searches, are given in a bibliography.

There are many problems with this book. Obviously a book unchanged since 1955 is dated. Dr. Hyypio recognized that many species described by Muenscher have had their common and/or scientific names changed since Muenscher's time. He provided Appendix I where updated scientific names are given and Appendix II where standardized common names, formulated by the Weed Science Society of America, are listed. Unfortunately, several names not changed by Dr. Hyypio in 1979 have been altered subsequently in *Flora Europea* or other standard European works (e.g. *Agropyron repens.* (L.) Beauv. was changed to *Elymus repens* (L.) Gould. [And since this review was written it has become *Elytrigia repens* (L.) Nov.] Also by 1979 *Lychnis alba* (Mill), White Cockle, was already known as *Silene alba* (Mill) E. H. L. Krause and since that time has been termed *Silene inflata, S. pratensis* and (most recently) *S. latifolia* Poiret). Hyypio's common names do not necessarily agree with the Canadian common names as found in such publications as *Ontario Weeds, Weeds of Canada, Common and Botanical Names of Weeds in Canada* or the Biology of Canadian Weeds series in the *Canadian Journal of Plant Science.* Muenscher's book is also dated or incorrect in its weed distributions. Many species that are now very important weeds in this country (e.g. *Amaranthus powellii, Abutilon theophrasti, Panicum capillare, Barbarea vulgaris, Poa annua* and *Echinochloa crusgalli*) are not listed as occurring in Canada. Conversely, a weed that is now extremely rare or extinct throughout Canada and the USA, *Argrostemma githago* L. — Corn Cockle, is listed as "widely distributed throughout the United States" and is given a full treatment. Several new and important weeds in the USA and Canada (e.g. *Panicum miliaceum* L. — Proso Millet) are not mentioned. In addition to the errors of nomenclature, distribution, and biological details, there are defects in the brief section on chemicals. Muenscher does not include any specific recommendations but he does refer the reader to annual publications on weed control. Unfortunately, the "Eastern and Western Sections, National Weed Committee of Canada, Proceedings" are no longer known by these titles, "Weeds" is now *Weed Science*, and periodicals beginning after 1955 are not mentioned. The section on biological control of weeds is even more dated.

In addition to the foregoing problems the book has other inherent deficiencies. The drawings of weeds are somewhat fuzzy and lacking in detail; they are much inferior to those in a current edition of *Ontario Weeds*, published by the Ontario Ministry of Agriculture and Food. Also, the drawings are often several pages away from the description of the plant, a result of different sequences in drawings and text. The useful data in the first 62 pages is not referenced in the index. Several of my students have missed important data on the biology of a particular weed because they did not know that Muenscher included the species in question in one of his tables in the initial chapters.

In summary, this book will have very limited use for most Canadians interested in weeds. It certainly should be in libraries as a useful reference and the reissue in paperback will facilitate its acquisition for this purpose.

PAUL B. CAVERS

Department of Plant Sciences, The University of Western Ontario, London, Ontario N6A 5B7

ENVIRONMENT

Ecology and Our Endangered Life-Support Systems

By E. P. Odum. 1988. Sinauer, Sunderland, Massachusetts. 212 pp., illus. U.S.$14.95.

To those of us raised to believe in the separation of ecology and environmentalism, Odum's *Ecology and our Endangered Life-Support Systems* is slightly shocking. Although at times I found the synthesis awkward, it is timely to instruct future would-be ecologists and citizens in the Leopold school of land ethics.

Oddly, I was unmoved by the Prologue, a dramatic recounting of an imperilled Apollo mission. Despite the attempt to connect Apollo's vulnerability to the embattled life support systems of Earth, I did not find that the book began in earnest until Chapter 3, The Ecosystem. The chief difference that sets this book favorably apart from Odum's 1963 *Ecology*, is that while it provides the more traditional curricula such as biochemical cycles, population ecology, succession, and ecosystem types, these all are ultimately discussed in their relationship with current human mismanagement of global affairs. For example, the analogy is made between successions of ecosystems and human societies, and while maximizing production may be an appropriate occupation for young ecosystems and civilizations, in natural ecosystems a "protective" strategy takes over. As biomass exceeds productivity and nutrients are locked away in biomass, the more limited resources are increasingly committed to maintenance and not growth. In parallel, Odum suggests that in developed urban industrial centres energy and resources must now be devoted to services which "maintain what is already developed and pump out the disorder inherent in any complex high energy system".

If Odum plans a third book on this theme, I think it should go into more detail on practical alternatives to current problems. Examples of successful and potential, sustainable replacement technologies are needed to counteract the more easily accessible examples of eco-crisis. I would like to see presentation of how alternative systems work, from pulping of wood by white rot fungi, microbial alternatives to straw burning, traditional principles of crop rotation and allee cropping, to the long practice of biogas generation in Asia.

Overall, I have little bad to say about this book. It could fill the introductory ecology text niche very neatly. It does not attempt to cover all the major figures in ecology by any means, but there is good smattering of Darwin, Clements/Gleason, Tansley, Lotka, Harper, Connell and Lovelock, and others. It is short, well-informed, and readable, in marked contrast to the overwhelming, pretty texts that now belabour the minds and arms of students.

NICK HILL

Department of Biology, Mount Saint Vincent University, Halifax, Nova Scotia B3M 2J6

State of Washington Natural Heritage Plan

Washington Natural Heritage Program. 1989. Department of Natural Resources, Olympia, Washington. 164 pp., illus.

This report will interest conservation biologists. It presents the status of one of the leading Natural Heritage Programs in the United States. The Washington Natural Heritage Program is the clearing house for information on Washington State's Natural Area System which presently contains eighty-four natural areas. The Washington State Natural Heritage Program has published a Natural Heritage Plan on a biennial basis since 1983. This report is the 1989 edition.

This plan contains an inventory of the "elements" presently in the Natural Area System. Elements are plant communities, rare animal and plant species, equatic systems, and other natural features including geologic features. The known elements for the seven physiographic regions of the State of Washington are listed with the degree of their representation in the Natural Area System. Those elements which are poorly represented, or not represented at all, are identified as needing further work.

This plan identifies the need to obtain better representation of marine ecosystems, wetland systems, and geological features. These elements are also poorly represented in the natural area systems of other states. This report contains plans to improve their representation in Washington State. These plans are positive indicators of the greater attention that these types of elements are starting to receive from the natural area community.

This report also contains an inventory of the elements present in each natural area that is

presently part of Washington State's Natural Heritage Program. This information will be of great interest to vegetation scientists, autecologists, and geologists interested in conducting research in Washington State's natural areas.

This plan is presented on high quality paper; it is a 11″ x 8½″ softbound. Much of the information is presented in the form of lists which permit rapid reading. The specific information on poorly represented rare species and plant communities will interest field biologists of the Pacific Northwest. The status and organization of this successful Natural Heritage Program presented in this publication will serve as an valuable example for biologists working on establishing or improving natural area systems elsewhere.

BLAINE H. M. MOOERS

111 NW 11th Street, Apartment 201, Corvallis, Oregon 97330

MISCELLANEOUS

The Field Naturalist: John Macoun, the Geological Survey, and Natural Science

By W. A. Waiser. 1989. University of Toronto, Press. Toronto, Buffalo, London. xxxiv + 253 pp., illus. $30.00.

Irish born John Macoun (1831-1920) holds a special place in the history of Canadian science. Emigrating to the backwoods of Ontario in 1850, Macoun trained as a teacher, but made his name as a botanist and naturalist with the Canadian government.

In the 1870s, following a chance encounter with Sanford Fleming, engineer-in-chief of the Canadian Pacific Railway, Macoun became government advisor on the agricultural potential of the Canadian northwest. In contrast to the findings of Captain John Palliser (1857-1859), Macoun's initial report on the suitability of the land was positive, and fitted the government's purposes. He made four more surveys in the 1870s, becoming increasingly enthusiastic about western Canada. His *reward* was an appointment in 1881 to the Geological and Natural History Survey of Canada.

As Dominion Botanist, Macoun began a large-scale collection of Canadian plants. He also collected birds, mammals, and other animals. With these he attempted to build up the botanical and zoological collections of the Survey. He corresponded with collectors across Canada and the information he obtained from them was included, together with his own findings, in *Catalogue of Canadian Plants* (1883-1986) and later in *Catalogue of Canadian Birds* (1900-1904).

Macoun, a self-trained scientist, became known as a naturalist *par excellence*. In spite of his stature, he had to rely, however, on the expertise of better trained British and American colleagues first to name and later to classify species for him.

The Field Naturalist illuminates an often neglected aspect of Canadian science — the importance of political connections. Such connections can result in the appointment of less than competent people to high positions, to the detriment of science. W. A. Waiser convincingly argues that Macoun's extreme self-confidence masked his lack of taxonomic expertise. He may have convinced politicians that he was an expert botanist and zoologist, but it was much harder to impress an increasingly Darwinian scientific community. In fact, throughout his long career Macoun continued to function like an early 19th century naturalist — (collector and taxonomist). Although at the time formal education was not yet necessary to become a natural scientist, wide reading of the works of Darwin, Wallace, and others had helped many autodidactes to change their thinking and engage in new forms of scientific investigations. Macoun, perhaps by inclination, or the lack of time for such readings, did not advance in his scientific approach. His science remained rooted, therefore, in the 19th century.

In all fairness, Macoun laboured under difficult conditions. He had no opportunity to consult other large collections in Canada — there were none! So he had to send plant and animal specimens abroad for identification. Moreover, space for housing the collection of the Survey remained at a premium, and funds were generally scarce. In spite of all this, Macoun insisted on large-scale surveys of the Canadian flora and fauna. Unavoidably, such surveys remained superficial and ultimately detrimental to the development of Canadian botany and zoology.

Macoun's career not only points at the importance of political mentors. From this book it is also evident that during Macoun's life-time, the correspondence and exchange by Canadians with American scientists had slowly replaced earlier reliance on European science. This supports the growing view that after 1850, Canadian science developed in a North American context.

I highly recommend this thoroughly researched, well written and illustrated book, as the perfect companion volume to the *Autobiography of John Macoun*, published by the Ottawa Field-Naturalists' Club in 1979. The divergent views of the same events, as seen through the eyes of Macoun and his

biographer, provide new dimensions to Macoun's career and the development of Canadian natural history.

MARIANNE GOSZTONYI AINLEY

4828 Wilson Avenue, Montreal, Quebec H3X 3P2

The Encyclopedia of Animal Evolution

By B. J. Barry and A. Hallam. 1987. Facts on File, New York. 152 pp., illus. U.S.$24.95; $33.95 in Canada.

For over a century, evolutionary theory has been recognized by scientists and naturalists as one of the basic, unifying concepts in understanding present and past life. For the general public, however, and especially those people with religious training, evolution remains mysterious and even threatening. These unfortunate circumstances are partly due to conflict in beliefs and the viewing of humans as apart from and above the rest of the natural world. However, the difficulty of entering a complex field of biology, with such overwhelming and sometimes technical data, also hinders broader interest in, and appreciation of, evolution. With imaginative presentation, fossil species and evolutionary processes can kindle widespread fascination, such as the resurgence in popularity of dinosaurs and their habits.

This 143-page encyclopedia is an admirable effort by 21 authors and two editors to highlight the various topics relating to the evolutionary history of living forms. The text consists of six chapters. The first explores the formation of fossils, time scale, and panoramas of plants and animals typical of each period. I would like to have seen early fishes dealt with in more detail. The second chapter, "The Background of Evolution", reviews the various theories concerning the origins, design, and evolution of life, from the Greek philosophers to Darwin and Wallace, and the systems of classification that have been invented to give order to the millions of species that have inhabited the earth. "The Course of Evolution" assesses the evidence for evolution, with sections on multi-cellular organisms, conquest of water, land, and air, massive extinction, trends, and missing links. "Consequences of Evolution" deals with the origin of life, homology, adaptation, and diversity. Genetics and the origin of species are explained in fair detail in "Mechanisms of Evolution", while the final chapter covers the development of humans and a discussion of the controversies that evolution has spawned right up to the present day.

This book is packed with exciting information on past communities (e.g., coral reefs, swamps), describing how species lived, evolved into new forms, or died out. The inter-relatedness of ecosystem constituents is followed through time, like an ever-changing scene of living things. Reading the book reminds one of watching a high-speed movie, with species' fortunes riding on chance, mutation, natural selection, and continually altering environmental challenges from land upheavels, erosion, invasion of seas, continental drift, and land bridges. Who can fail to marvel on learning that for most of humanity's three-million-year record, individuals numbered only in the thousands, and that bipedal *Australopithecus* measured only one metre in height.

The content and level are directed at the general public; however, the pages on genetics are, of necessity, more technical and will probably lose some readers. Material is presented in a professional manner, letting the facts, ideas, and alternative theories speak for themselves, without the sensationalism and wild extrapolation frequently seen in popular science magazines. The book is richly illustrated in an almost bewildering variety of techniques by seven artists and numerous photographers. While most paintings complement the storyline quite nicely (e.g., the evolution of humans), some (e.g., the mammal panoramas) are drawn lacking much knowledge of anatomy or of realism in facial expression, and are inferior to the illustrations of prehistory currently available in other books.

This publication is worth having in your personal library. Lessons from the past on the effects of global warming and cooling (from atmospheric gases and dust) on environments and biological communities, will not escape your attention.

ROBERT E. WRIGLEY

505 Boreham Boulevard, Winnipeg, Manitoba R3P 0K2

Origins of Life

By Freeman Dyson. 1985. Cambridge University Press, Cambridge. ix + 81 pp., illus. U.S.$7.95.

Clay Minerals and the Origin of Life

Edited by A. G. Cairns-Smith and H. Hartman. 1986. Cambridge University Press, Cambridge. xiv + 193 pp., illus. U.S.$34.50.

For a long time ideas about the origin of life were matters of mythology and folklore. Serious speculation about the origin of life on earth can probably be said to have begun in the 1920s with the publication of a book entitled *The Origin of Life* by the Russian biochemist A. I. Oparin. The emphasis in biochemistry at that time was on enzymes and other proteins, and on metabolic pathways. Not much was known about the chemistry of nucleic acids and nothing at all about their biological significance. In this intellectual climate Oparin supposed that organic compounds of increasing complexity accumulated in the environment of the primitive earth, gradually polymerizing into proteins, lipids, and other substances, which in turn coalesced into primitive cells capable of rudimentary metabolism. Support for this theory was subsequently provided by experiments which demonstrated that many biochemically important compounds could be formed with surprising ease under conditions that seem likely to have existed on the primitive earth.

Later, however, with the development of information theory and the understanding of the role of nucleic acids in reproduction and growth, the Oparin theory fell out of favour. Emphasis was placed on the role of self-replicating molecules, possibly ribonucleic acids (RNA), in life's beginnings. Manfred Eigen is probably the most eminent of a number of scientists who helped to develop this line of thought. Still another theory, which attributes an essential role to clay particles in the origin of life, has been developed by A. G. Cairns-Smith and is discussed below.

The first of the two books under review is by a distinguished physicist, Freeman Dyson, who like a number of physicists before him has turned his mind to basic problems in biology. He stresses the distinction between the origins of metabolism (Oparin) and of self-replication (Eigen), and goes on to argue that life probably began twice. The first organisms arose in some such way as Oparin suggested, and were capable of metabolism without exact replication. The second kind of organisms, capable of replication but not metabolism and probably consisting of nucleic acids, must have arisen as obligate parasites in the earlier organisms. Gradually the metablic and the self-replicating components developed a symbiotic interdependence leading to living organisms as we know them today.

The distinction between metabolism and self-replication may not be quite as sharp as Dyson supposed. Recent work has shown that some types of RNA have catalytic capabilities and may be regarded in fact as non-protein enzymes (See "RNA as an enzyme" by Thomas R. Cech in the *Scientific American*, November 1986). Thus at some stage in the origin of life the two basic processes may have been carried out by the same molecules. However functionally the two processes are quite distinct. Perhaps the origin of self-replication may be seen as the acquisition of a new property by a pre-existing kind of molecule rather than as the appearance of a new kind.

Probably the most original part of the book is Chapter 3 in which the author attempts a quantitative treatment of the Oparin theory. He does this by constructing what he calls a "toy model" of the theory, based on concepts derived from such diverse fields as population biology and the theory of ferromagnetism, with even a passing allusion to musical theory. This leads to a plausible picture of a primitive cell containing around 10 000 polymeric molecules composed of about as many monomers as there are amino acids in modern proteins. These are about as specific in their catalytic activity as good inorganic catalysts.

Dyson refers several times to another small book, also by an eminent physicist and also published by Cambridge University Press, after which his own book is patterned to a certain extent. This book, by Erwin Schrodinger, was called *What is Life?* and appeared in 1944. Like Dyson's book it was well-written and interesting, and it was widely read. Many believe it played a part in steering biological research in the direction that lead to the molecular biology of today. In particular, as Dyson points out, Schrodinger astutely suggested that biologists would do well to study the structure of the gene. In the final chapter of his book, Dyson, following Schrodinger's example, suggests that future biologists would do well to investigate the population structure of homeostatic systems of molecules. It will be interesting to see if this suggestion will prove as fruitful as Schrodinger's.

The Cairns-Smith theory of the origin of life is the subject of the second book, which is based on the papers presented at a workshop on Clays and the Origin of Life held at Glascow University in July 1983. The theory seems to have arisen from earlier suggestions that the adsorption of organic molecules onto clay particles may have played a role in the origin of life. Cairns-Smith has taken

this idea several steps further and has suggested that clay particles themselves may have formed the basis for the first living organisms. He suggests that clay particles would be capable of storing information by means of cation substitutions, crystal dislocations, and other deviations from perfect crystallinity. It is supposed that these imperfections could be copied as new layers of clay are formed on the surfaces of pre-existing particles. Over a long period of time organic compounds would appear, their formation perhaps catalyzed by the clay, and play an increasingly important role in the replication of the clay genes. These compounds might include RNA, or something like it, which would eventually replace clay as the repository and transmitter of information in what he calls the "genetic takeover" leading to something similar to life as we know it today.

The theory is not expounded at length in this book. The reader may find a popular exposition with arguments in its support in an earlier book by Cairns-Smith, *Seven Clues to the Origins of Life*, previously reviewed in *The Canadian Field-Naturalist* (102: 766) by F. W. Schueler, or in an article by Cairns-Smith in the *Scientific American*, June 1985. The book under review contains an intriguing collection of facts and speculations about clays on the earth and elsewhere in the solar system, and their structure (with beautiful electron micrographs) and properties insofar as these are relevant to the theory. The book concludes with a chapter on Questions and Prospects in the form of a conversation between the editors. I must confess I found myself still unconvinced at the end, but perhaps as a biochemist I am not sufficiently sympathetic towards the invasion of my field by geochemistry. I nevertheless found the book extremely interesting.

These two books are very different in many ways. The first is a closely argued essay by a single author while the second is a collection of ideas by a number of authors, given a certain unity by the work of the editors. However, both books demonstrate that it is possible to speculate in some detail and in an interesting, and perhaps even plausible, way about the origin of life. I think this in itself is remarkable. Both are easy to read, except perhaps for a few pages in Dyson's book in which he develops his model. Both should give pleasure to any biologist who has ever wondered how life began.

R. M. BAXTER

Lakes Research Branch, National Water Research Institute, Burlington, Ontario L7R 4A6

YOUNG NATURALISTS

The Bug Book

By Hugh Danks. 1987. Somerville House, Toronto. 64 pp. (with Bug Bottle). $9.95.

The Bug Book comes packaged in a *Bug Bottle* and together they work toward bringing bugs alive for the young naturalist.

The *Bug Bottle* is a clear, heavy-duty plastic container with a perforated slide-on lid. Both the heavy-duty and plastic aspects of the container make it much safer than a glass jar that might have been scavenged from the kitchen. It's suitable for children, even pre-schoolers.

The *Bug Book* effectively compliments the intended use of the *Bug Bottle*. It includes sections entitled: Bug and Bottle Tips, Bug Chart, and Bug Bottle Projects. The bulk of the book is a very simplified approach to "bugs", suggesting where and how to catch bugs, along with some very basic identification. For example, in one section entitled, Look on Leaves, the book assists the young learner distinguish between Leaf Beetles, Leafhoppers, Caterpillars, Ladybugs, and Stink-bugs. Each identification discusses appearance, food, and notes of a general nature. Also included are "warnings" directing the reader-collector not to handle certain bugs. As a bonus, the book is small in size and of paper that will resist some dirt and moisture exposure, both advantages in its' attempt to "survive" use by children.

Recommended for children 10 and under by the publishers, most of this age group will be able to utilize the *Bug Bottle* but most will have difficulty with the book. I think the real value of this book-bottle is that it creates an excellent opportunity for young children and an adult to explore the out-of-doors together. On several afternoons with my toddlers, I was fascinated with how excited and interested they were in seeing "bugs" at close range. With my assistance, we were able to minimize their frustration in attempting to capture specimens in their *Bug Bottle*.

I'd recommend this book-bottle package for any parent looking to enjoy and share an outdoor experience with their pre-schooler. As a science activity for junior and primary aged children, it has great potential.

PETER CROSKERY

RR#1, 50 Ridge Rd. W., Grimsby, Ontario L3M 4E7

Animal Movement

By Tony Seddon. 1989. Facts on File, New York. 62 pp., illus. U.S.$13.95; $18.95 in Canada.

Anticipating the Seasons

By Jill Bailey. 1989. Facts on File, New York. 62 pp., illus. U.S.$13.95; $18.95 in Canada.

Birds of Prey

By Jill Bailey. 1988. Facts on File, New York. 62 pp., illus. U.S.$13.95; $18.95 in Canada.

Facts on File publications in the Nature Watch Series were designed and intended for a children's reading audience. The three volumes I reviewed all follow a similar format. Each book is generously illustrated with color photographs and illustrations. Information contained is presented in a two-page format so that the book, when open, presents a single topic or aspect of the book's overall theme. At the bottom of each page is a reference arrow listing which tells the reader where else in the book similar or complimentary information on the page's topic is located. Each contains a glossary near the end of the book and an index. Two of the three books have reference or additional reading lists while the third doesn't. Only one of the three books, *Animal Movement*, has questions contained within the text and an answer page appended. All books are equal in length, 62 pages long.

Animal Movement reviews how animals move. It examines large land mammals, microscopic organisms, fish, birds, and various invertebrates. The mechanics of movement are examined as well as the reasons for moving. *Anticipating the Seasons* reviews how animals respond to changing environmental conditions including seasonal changes as well as daily changes. *Birds of Prey* examines the biology of a specific group of birds. No book focuses on single or individual species but rather illustrates principles using a wide range of animal examples.

Considered as a unit, the overall weakness of the books is the Glossary. In *Birds of Prey*, the definitions of territory and incubate are inaccurate. In *Anticipating the Seasons*, I would argue with the provided definitions for plankton, diurnal, algae, emigration, and hibernation. The glossary in *Animal Movement* is more acceptable.

Since each book is attempting to present a lot of information in a concise fashion, it is to be expected that argument could be taken with some of the material. Each book has a few inaccuracies. Some examples include: in *Anticipating the Seasons*, algae includes more than diatoms (p.19) and page 51 appears not to have been proof read, as it contains several errors such as missing words; in *Animal Movement*, a subtitle of Life on Six Legs appears above an eight legged spider; in *Birds of Prey*, it is suggested that owls "can turn their heads through almost a full circle" and that eagles live for 80+ years, neither statement is correct.

Even considering these minor flaws, these books are excellent for children. Their design gives them a reference book content but in a pleasant and readable format. Intermediate age students, grade 4 to 8, should enjoy these books.

PETER CROSKERY

RR#1, 50 Ridge Rd. W., Grimsby, Ontario L3M 4E7

Birdwise

By Pam Hickman. 1988. The Federation of Ontario Naturalists, Toronto. 96 pp., illus. Cloth $19.95; paper $9.95; plus $2.50 postage.

This children's book is divided into five sections. The first section describes, in simple terms, nomenclature and bird anatomy. The second section covers topics such as nesting, migration, and overwintering. The next section takes a closer look at owls, gulls, hummingbirds, and woodpeckers. The fourth section examines birdwatching, photography, and sketching. The final section deals with birdfeeding, bird care, and conservation. It concludes with a board game. Throughout the sections are quizzes, numerous black-and-white illustrations, additional details, examples, and things-to-do. A table of contents and a two-page index complete the book.

The layout of the book is very good, with each topic within a section usually being covered in a two-page spread. The top left gives an eye-catching title in bold print; the remainder is made up of paragraphs and illustrations. Many of the paragraphs are "headlined" with titles designed to attract a youngster's attention. The author is generous with her use of boxes which provide examples, activities, and further details. The layout is one that is ideal for young inquiring minds.

The level of detail and general tone of the text are good. The text is geared directly towards the young reader and the many examples and things-

to-do will help capture almost any youngster's interest. The book's general approach is just about right for the book's intended readership.

Black-and-white illustrations by Julie Shore appear on each page. Although these illustrations vary in quality and accuracy, on the whole they contribute greatly to the book, notwithstanding the illustration of an American Kestrel catching a rabbit!

However, the above good points are seriously negated by the text itself. Every three or four pages, on average, there is something that is not quite right. Sometimes it is something in the subject matter itself; other times it is the way the subject matter is described. Examples are:

— factual errors, such as claiming that the Common Loon is the same as the Black-throated Diver;
— overzealous generalizations, such as giving the impression that all parent birds make several hundred trips to the nest to the nest each day;
— ambiguities; for instance, it is sometimes confusing as to whether the author means a species of bird or an individual bird (such as when she describes the concept of range);
— poor tie-ins within topics, such as on the topic of nomenclature, which starts off by describing the naming of individuals; then jumps into how some common names are assigned; and concludes with a brief description of scientific names. This topic could have been improved by better links between paragraphs and/or by having the opening paragraph introduce the notions of common names, scientific names, and names of individuals;
— unclear points, such as one paragraph which says that knowing a bird's name is not the most important thing in birdwatching and then, without then telling us what the most important thing is and without telling us what the first way to identify a bird is, promptly tells us that there are many other ways to identify a bird. Whatever points the author may have been trying to make are completely unclear to this reviewer;
— incomplete material, such as in the section on bird feeding which neglects to alert the reader that birds might not come to the feeder for quite some time (or even at all) or that squirrels might come as well as, or instead of, birds; and
— misleading statements, such as the one that implies that the Audubon Bird Call attracts birds by imitating them.

The book's poor writing and factual shortcomings may confuse and/or mislead young readers and may cause their parents to scratch their heads or reach for their red pens. Parents knowledgeable about birds who use this book as an educational vehicle will be put in the unenviable position of frequently having to tell their children that the book is wrong.

It is a shame that the text is so flawed; had there been a thorough proof reading by someone more knowledgeable about birds and more diligent editing, *Birdwise* could have been an excellent teaching aid.

In summary, this book is only recommended for those people who are prepared to work around its deficiencies; such people will find the book to be useful in making their children birdwise.

STEPHEN GAWN

67-D Bowhill, Nepean, Ontario K2E 6S8

The Whooping Crane: A Comeback Story

By Dorothy Hinshaw Patent. 1988. Clarion Books, New York. 88 pp. illus. US$14.95.

This attractive and well-illustrated small volume tells the story of the rescue of the Whooping Crane. It is suitable for young readers probably between the ages of 8 to 11, although younger children may need some help with the longer words. The book is a little wordy but not unduly so, and it traces the Whooping Crane story in five chapters.

The first chapter starts with a description of the cranes themselves and the Crane family. Other species of cranes are mentioned and some are illustrated, and there is reference to the birds' long history of contact with mankind, from ancient Egypt to modern Japan. This is followed by a section on how the whooper population became endangered. The life history of the birds is briefly chronicled with a full chapter devoted to their winters on the Texas Gulf Coast. The rescue program is then described in two chapters — one on "Creating a New Flock" — and the final chapter discusses the future of the Whooping Crane.

The book is an interesting and factual presentation of this now familiar story, giving an account of some of the pitfalls and problems that have been encountered, and explaining the key decisions that have been made. Unless you are very familiar with the Whooping Crane story you'll likely learn something about the birds yourself from it.

Each chapter is divided into clearly marked sections with sub-headings, and is profusely illustrated — it is difficult to open a page without encountering one or more either coloured or black-

and-white photographs. These are well chosen and form an excellent complement to the text. There is also a map of the migration route and a short index. The facts seemed generally accurate, and I found only one typographical error. The book is sturdily bound in hardcover, and well-produced, although it seems rather expensive for its size.

This volume is an excellent introduction for a young person to one of the more interesting stories in conservation, and should be a good vehicle for stimulating interest in wildlife and nature as a whole.

CLIVE E. GOODWIN
103-45 LaRose Avenue, Weston, Ontario M9P 1A8

NEW TITLES

Zoology

America's neighborhood bats. 1988. By Merlin D. Tuttle. University of Texas Press, Austin. vii + 96 pp., illus. Cloth U.S. $19.95; paper U.S.$9.95.

Animals in the classroom: selection, care, and observations. 1989. By David C. Kramer. Addison-Wesley, Menlo Park, California. 234 pp., illus. U.S.$28.

*__Arizona game birds.__ 1989. By David E. Brown. University of Arizona Press, Tucson. xiv + 307 pp., illus. U.S.$19.95.

*__Audubon wildlife report 1989/1990.__ 1989. Edited by William J. Chandler. Academic Press, San Diego. xix + 585 pp., illus. U.S.$39.95.

Biology and exploitation of the minke whale. 1989. By Joseph Horwood. CRC Press, Boca Raton, Florida. c240 pp. cU.S.$97.50 in U.S.A.; cU.S.$115.00 elsewhere.

*__The biology of butterflies.__ 1989. Edited by R. I. Vane-Wright and P. R. Ackery. Princeton University Press, Princeton. xxv + 429 pp., illus. U.S.$29.95.

The bird illustrated, 1550-1990: from the collections of the New York Public Library. 1988. By Joseph Kastner. Abrams, New York. 128 pp., illus. U.S.$29.95.

Birds of the Kingston region: a natural history. 1989. By Ron Weir. Quarry Press, Kingston. 368 pp. $35.95.

Birds of prey: an identification guide to the raptors of the world. 1988. By James Ferguson-Lee, Philip Burton, Kim Franklin, and David Mead. Christopher Helm (distributed by Houghton Mifflin, Boston). 512 pp., illus.

†__Birds of the Seward Peninsula, Alaska: their biogeography, seasonality, and natural history.__ 1989. By Brina Kessel. University of Alaska Press, Fairbanks. x + 330 pp., illus. U.S.$34.95

*__Bites and strings: the world of venomous animals.__ 1989. By John Nichol. Facts on File, New York. 207 pp., illus. U.S.$19.95; $25.95.

*__Crocodiles and alligators.__ 1989. Edited by Charles A. Ross and Stephen Garnett. Facts on File, New York. 240 pp., illus. U.S.$35.

The evolution of culture in animals. 1989. By John Tyler Bonner. Princeton University Press, Princeton. 216 pp., Illus. Cloth U.S.$27.50; paper cU.S. $9.95.

*Familiar amphibians and reptiles of Ontario. 1989. By Bob Johnson. Natural Heritage/Ntural History, Toronto. 168 pp., illus. $9.95 + $2 postage.

*__A field guide to birds of the USSR.__ 1989, 1984. By V. E. Flint, R. L. Boehme, Y. V. Kostin, and A. A. Kuznetsov. Translated by N. Bourso-Leland. Reissue of 1984 edition. Princeton University Press, Princeton. xxxi + 353 pp., illus. + plates. U.S.$27.50

*__A guide to the birds of Panama with Coastal Rica, Nicaragua, and Honduras.__ 1989. By Robert S. Ridgely and John A. Gwynne, Jr. 2nd edition. Princeton University Press, Princeton. c608 pp., illus. cU.S.$49.50.

A guide to the birds of Puerto Rico and the Virgin Islands. 1989. By Herbert A. Raffaele. Princeton University Press, Princeton. c220 pp., illus. cU.S.$15.95.

Kalahari hyaenas. 1989. By M. G. Mills. Unwin Hyman, Winchester, Massachusetts. 350 pp., illus. U.S.$55.

†__Mammals of the neotropics, volume 1, the northern neotropics: Panama, Columbia, Venezuela, Guyana, Suriname, French Guiana.__ 1989. By John F. Eisenberg. University of Chicago Press, Chicago. c500 pp., illus. Cloth U.S.$85; paper U.S.$34.95.

Marine invertebrates of the Pacific Northwest. 1988. By Eugene N. Kozloff, *et al.* Revised edition. University of Washington Press, Seattle. x + 511 pp., illus. U.S.$35.

*__An odyssey in time: the dinosaurs of North America.__ 1989. By Dale Russell. University of Toronto Press, Toronto. 239 pp., illus. $45.

†__Oklahoma herpetology: an annotated bibliography.__ 1989. By Chales C. Carpenter and James J. Krupa. University of Oklahoma Press, Norman. 258 pp. U.S.$22.95.

***Owls: their natural and unnatural history.** 1989. By John Sparks and Tony Soper. Revised edition. Facts on File, New York. 240 pp., illus. U.S.$22.95; $29.95.

***Predators and predation: the struggle for life in the animal world.** 1989. Edited by Pierre Pfelfer. Facts on File, New York. viii + 419 pp. U.S.$50.

***Rare birds in Britain and Ireland.** 1989. By J. N. Dymond, P. A. Fraser, and S. J. M. Grantlett. Buteo, Vermillion, South Dakota. 366 pp., illus. U.S.$55.

Save the birds. 1989. By A. W. Diamond and R. Bateman. Breakwater Books. St. John's, Newfoundland. 384 pp., illus. $75 plus $2 shipping.

Sharks in question: the Smithsonian answer book. 1989. By Victor G. Springer and Joy P. Gold. Smithsonian Institute Press, Washington. 187 pp., illus. Cloth U.S.$39.95; paper U.S.$15.93.

Sharks of the order Carcharbiniformes. 1988. By L. J. V. Campagno. Princeton University Press, Princeton. 650 pp., illus. U.S.$99.50.

South American birds: a photographic aid to identification. 1988. By John S. Dunning. Harrowood Books, Newton Square, Pennsylvania. 352 pp., illus. Cloth U.S. $47.50; paper U.S.$35.

***Swallows and martins: an identification guide and handbook.** 1989. By Angela Turner and Chris Rose. Thomas Allen and Son, Markham, Ontario. viii + 258 pp., illus. $51.95.

What is an animal? 1988. Edited by R. Ingold. Unwin Hyman, Winchester, Massachusetts. 208 pp., illus. U.S.$39.95.

***Where have all the birds gone: essays on the biology and conservation of birds that migrate to the American tropics.** 1989. By John Terborgh. Princeton University Press, Princeton. c202 pp. Cloth U.S.$45; paper U.S.$14.95.

Wildlife of the Florida Keys. 1989. By James D. Lazell, Jr. Island Press, Covelo, California. 254 pp., illus. Cloth U.S.$31.95; paper U.S.19.95.

Zoogeography of fresh waters — Volume 1: General distribution and dispersal of freshwater animals: Volume 2: Distribution and dispersal of freshwater animals in North America and Eurasia; and **Volume 3: distribution and dispersal of freshwater animals in Pacific areas and South America.** 1989, 1990, and 1990. By Petru Banarescu. AULA-Verlag, Wiesbaden, West Germany. 540 pp., illus., 580 pp., illus., and 350 pp., illus. 3 volumes DM 560.

Botany

***Flowering plants of Florida: a guide to common families.** 1989. By Wendy B. Zomlefer. Biological Illustrations, Gainesville, Florida. xi + 207 pp., illus. + plates. U.S.$25 + U.S.$2 postage.

*Henry Potter's field guide to the hybrid ferns of the northeast. 1989. By Frank and Libby Thorne. Vermont Institute of Natural Science, Woodstock. 79 pp., illus. U.S.$14.95 + U.S.$2.50 handling.

***Lichens of California.** 1988. By Mason Hale, Jr. and Mariette Cole. University of California Press, Berkeley. vii + 254 pp., illus. + plates. U.S.$14.95.

***The names of plants.** 1989. By D. Gledhill. Second edition. Cambridge University Press, New York. vi + 202 pp. Cloth U.S.$44.50; paper U.S.$14.95.

Plant tropisms and other growth movements. 1989. By J. W. Hart. Unwin Hyman, Winchester, Massachusetts. 240 pp., illus. U.S.$55.

Saving the tropical forests. 1988. By Judith Gradwohl and Russell Greenberg. Island Press, Covelo, California. 207 pp., illus. U.S.$24.95.

The shortgrass prairie. 1988. By Ruth Carol Cushman and Stephen R. Jones. Pruett, Boulder, Colorado. 118 pp., illus. U.S.$18.95.

***The vascular plants of British Columbia, part 1: gymnosperms and dicotyledons.** 1989. By George Douglas, Gerlald Straley, and Del Meidinger. Crown Publications, Victoria. 208 pp. $22.

Environment

Air pollution and acid rain: the biological impact. 1988. By A. Wellburn. Wiley, New York. 274 pp. U.S.$48.95.

Aquatic toxicology and hazard assessment, Volume 12. 1989. Edited by U. M. Cowgill and L. R. Williams. ASTM, Philidelphia. 445 pp., illus. U.S.$65.

Biodiversity. 1988. Edited by E. O. Wilson. National Academy Press, Washington. 534 pp., illus. U.S.$19.50.

The book of naturalists: an anthropology of the best natural history. 1988. Compiled by William Beebe. Princeton University Press, Princeton. 520 pp. Cloth U.S.$49.50; paper U.S.$14.95.

The challenge of global warming. 1989. Edited by Dean E. Abrahamson. Island Press, Covelo, California. 355 pp., illus. Cloth U.S.$34.95; paper U.S.$19.95.

Coastal marshes: ecology and wildlife management. 1988. By Robert H. Chabreck. University of Minnesota Press, Minneapolis. xiii + 138 pp., illus. Cloth U.S.$25; paper U.S.$12.95.

Crossroads: environmental priorities for the future. 1988. Edited by Peter Borrell. Island Press Covelo, California. 352 pp. Cloth U.S.$29.95; paper U.S.$17.95.

Ecological diversity and its measurement. 1988. By Anne E. Magurran. Princeton University Press, Princeton. 215 pp., illus. Cloth U.S.$45; paper U.S.$14.95.

The environment of life. 1988. Edited by Colin Tudge. Oxford University Press, New York. 256 pp., illus. U.S.$25.

From clocks to chaos: the rhythms of life. 1988. By Leon Glass and Michael C. Mackey. Princeton University Press, Princeton. xviii + 248 pp., illus. Cloth U.S.$45; paper U.S.$13.95.

Here to stay: a resource kit on environmentally sustainable development. 1989. DEC Book Distribution, Toronto. $25 + $2.50 postage.

Holistic resource management. 1988. By Allan Savory. Island Press, Covelo, California. 512 pp., illus. Cloth U.S.$39.95; paper U.S.$24.95.

Intermedia pollutant tranport modeling and field measurements. 1989. Edited by David T. Allen, Yoram Cohen, and Isaac R. Kaplan. Proceedings of a workshop, Los Angeles, 24-26 August 1988. Plenum, New York. c288 pp. U.S.$75.

Journey through a tropical jungle. 1988. By Adrian Forsyth. Simon and Shuster, New York. 80 pp., illus. U.S.$14.95.

Natural resources for the 21st century. 1989. Edited by Neil Sampson and Dwight Hair. Island Press, Covelo, California. 350 pp., illus. Cloth U.S.$34.95; paper U.S.$19.95.

*__Nature Wells Gray: the Clearwater Valley.__ 1989. By Trevor Goward and Cathie Hickson. Friends of Wells Gray Park, Kamloops. xv + 190 pp., illus. $11.

*__A neotropical companion: an introduction to the animals, plants, and ecosystems of the new world tropics.__ 1989. By John C. Kricher. Princeton University Press, Princeton. 450 pp., illus. Cloth U.S.$49.50; paper U.S.$16.95.

Patterns of life: biogeography of a changing world. 1989. By H. Meilke. Unwin Hyman, Winchester, Massachusetts. 340 pp. Cloth U.S.$50; paper U.S.$19.95.

Perspectives in ecological theory. 1989. Edited by Jonathan Roughgarden, Robert M. May, and Simon A. Levin. Princeton University Press, Princeton. 402 pp., illus. Cloth U.S.$60; paper U.S.$22.50.

The poisoned well: new strategies for groundwater protection. 1988. By the Sierra Club Legal Defense Fund. Island Press, Covelo, California. 225 pp., illus. Cloth U.S.$31.95; paper U.S.$19.95.

Population harvesting: demographic models of fish, forest, and animal resources. 1989. By Wayne M. Getz and Robert G. Haight. Princeton University Press, Princeton. 352 pp., illus. Cloth U.S.$49.50; paper U.S.$15.95.

Rehabilitating damaged ecosystems. 1988. Edited by John Cairns, Jr. CPC press, Boca Raton, Florida. 2 volumes, 208 pp. and 232 pp. U.S.$110.00 each in U.S.A.; U.S.$125 elsewhere.

Research priorities for conservation biology. 1989. Edited by Michael E. Soule and Kathryn A. Kohm. Island Press, Covelo, California. 110 pp., illus. U.S.$9.95.

Rivers at risk: the concerned citizen's guide to hydropower. 1989. By John D. Echeverria, Pope Barrow, and Richard Roos-Collins. Island Press, Covelo, California. 220 pp., illus. Cloth U.S.$29.95; paper U.S.$17.95.

*__Saskatchewan's playground.__ 1989. By W. Waiser. Friends of Prince Albert National Park, Waskesiu Lake, Saskatchewan. 160 pp., illus. $29.95.

The Sierra Nevada: a mountain journey. 1988. By Tim Palmer. Island Press, Covelo, California. 352 pp., illus. Cloth U.S.$31.95; paper U.S.$19.95.

A student's guide to the seashore. 1989. By J. and S. Fish. Unwin Hyman, Winchester, Massachusetts. 400 pp., illus. Cloth U.S.$55; paper U.S.$24.95.

To the Arctic: an introduction to the far northern world. 1989. By Steven B. Young. Wiley, New York. xiii + 354 pp., illus. U.S.$24.95.

Toxic contaminents and ecosystem health: a Great Lakes focus. 1988. Edited by Marlene S. Evans. Wiley, New York. 624 pp., illus. U.S.$99.95.

War on waste: can America win its battle with garbage. 1989. By Louis Blumberg and Robert Gottlieb. Island Press, Covelo, California. 325 pp. Cloth U.S.$34.95; paper U.S.$19.95.

Miscellaneous

The field guide to geology. 1988. By David Lambert, *et al.* Facts on File, New York. 256 pp., illus. Cloth U.S.$22.95; paper U.S.$14.95.

The gene hunters:: biotechnology and the scramble for seeds. 1989. By Calestous Juma. Princeton University Press, Princeton. 304 pp. Cloth U.S.$39; paper U.S.$14.95.

*__George Dawson: the little giant.__ By Joyce Barkhouse. Natural Heritage/Natural History, Toronto. 139 pp., illus. $12.95.

Satellite images: photographs of Canada from space. 1989. By Brian Banks. Camden House (distributed by Firefly Books, Willowdale, Ontario). 156 pp., illus. $29.95.

Scientific problem solving: an introduction to technology. 1989. By George Mills and John Aitken. David S. Lake, Belmont, California. 96 pp., illus. U.S.$10.95.

Statistical ecology: a primer of methods and computing. 1988. By J. A. Ludwig, and J. F. Reynolds. Wiley, New York. c352 pp. U.S.$34.95.

Statistics for the life sciences. 1989. By Myra L. Samuels. Dellen (Macmillan), San Francisco. xiv + 597 pp., illus. U.S.$31.

Time frames: the evolution of punctuated equilibria. 1989. By Niles Edlredge. Princeton University Press, Princeton. 340 pp., illus. cU.S.$8.95.

Books for Young Naturalists

The arctic fox. 1989. By Gail La Bonte. Dillon, Minneapolis. 60 pp., illus. U.S.$12.95.

The big fearon book of dinosaurs. 1989. By Diane Calbert Burlke, et al. David S. Lake, Belmont, California. 128 pp., illus. U.S.$10.95.

†**Birds: the aerial hunters.** 1989. By Martyn Bramwell. Facts on File, New York. 96 pp., illus. U.S.$17.95; $21.95 in Canada.

†**Birds: the plant- and seed-eaters.** 1989. By Jill Bailey and Steve Parker. Facts on File, New York. 96 pp., illus. U.S.$17.95; $21.95 in Canada.

Busy beavers. 1988. By Barbara M. Brownell. National Geographic Society, Washington. 32 pp., illus. U.S.$11.95.

The complete frog: a guide for the very young naturalist. 1989. By Elizabeth A. Lacey. Lothrop, Lee, and Shepard, New York. 72 pp., illus. U.S.$12.95.

Creatures of long ago: dinosaurs. 1988. By the National Geographic Society, Washington. 12 pp., illus. U.S.$19.95.

Desert giant: the world of the Saguaro cactus. 1989. By Barbara Bash. Sierra Club Books. San Francisco. 28 pp., illus. U.S.$14.95.

The dolphins and me. 1989. By Don C. Reed. Sierra Club Books, San Francisco. 135 pp., illus. U.S.$14.95.

Elephant seals. 1989. By Sylvia A. Johnson. Lerner, Minneapolis. 48 pp., illus. U.S.$12.95.

A first look at animals with horns. 1989. By Millicent E. Selsam and Joyce Hunt. Walker, New York. 32 pp., illus. U.S.$10.95.

The life cycle of a butterfly. 1988. By Terry Trevor and Margaret Linton. Bookwright, New York. 32 pp., illus. U.S.$11.90.

The life cycle of a rabbit. 1988. By John Williams. Bookwright, New York. 32 pp., illus. U.S.$11.90.

The life cycle of a sunflower. 1988. By Philip Parker. Bookwright, New York. 32 pp., illus. U.S.$11.

Lily pad pond. 1989. By Bianca Lavies. Dutton, New York. 32 pp., illus. U.S.$12.95.

The llama. 1989. By Gail LaBonte. Dillon, Minneapolis. 60 pp., illus. U.S.$12.95.

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Amphibians and reptiles in the diets of North American raptors. 1989. By David A. Ross, Wisconsin Endangered Resources Report 59. 33 pages. Available from Bureau of Endangered Resources P.O. Box 7921, Madison, Wisconsin 53707.

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Cover: Juvenile Arctic Ground Squirrels, *Spermophilus parryi parryi*, two days after emergence from natal burrow, Rankin Inlet, Northwest Territories. Courtesy Mark R. Simpson. See note on adult chasing weasel pages 473-474.

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The Canadian Field-Naturalist

Volume 104, Number 3 July–August 1990

Geographic Variation in Painted Turtles, *Chrysemys picta*, from Eastern Ontario and Southern Quebec

DAVID M. GORDON

Department of Zoology, University of Massachusetts, Amherst, Massachusetts 01003

Gordon, David M. 1990. Geographic variation in Painted Turtles, *Chrysemys picta*, from eastern Ontario and southern Quebec. Canadian Field-Naturalist 104(3): 347–353.

Painted Turtles, *Chrysemys picta*, were examined from nine localities in southwestern Quebec and eastern Ontario. The specimens were analysed with respect to the degree of seam disalignment in carapace scutes, pleural border widths, and the size of the plastron figure; characters used to distinguish the subspecies, *C. p. marginata* and *C. p. picta*. Attributes associated with the eastern subspecies, *C. p. picta*, were found in populations from southwestern Quebec: lower seam disalignments, wider border widths and smaller plastron figures. It has been previously suggested that *Chrysemys* populations in the Canadian Maritimes should be considered as a mixed assemblage of the subspecies *C. p. marginata* and *C. p. picta*. The results of this study support this view and suggest that these hybrid populations extend as far west as the Quebec-Ontario border.

Key Words: Painted Turtle, *Chrysemys picta,* intergradation, subspecific status, Quebec, Ontario.

The Painted Turtle, *Chrysemys picta* occurs over much of the North American Continent (Conant 1975). The species has been partitioned into four subspecies: *C. p. bellii* (Gray) in western Canada and the western United States, *C. p. dorsalis* Agassiz in the south-central United States, *C. p. marginata* Agassiz in south-central Canada and the central United States, and *C. p. picta* (Schneider) along the Atlantic coast.

Intergradation among these forms is well known and has been documented by Bishop and Schmidt (1931), Johnson (1954), Hartman (1958), Waters (1964), Ernst (1967, 1970), Pough and Pough (1968), Ernst and Ernst (1971), Ernst and Fowler (1977), and Groves (1983). The northeastern United States has been the focus of study, where populations of *Chrysemys picta* show a great deal of variation, and intergradation apparently occurs over a large geographic area (Allen 1899; Babcock 1933; Hartman 1958; Waters 1964, 1969; Pough and Pough 1968), but Canadian *C. picta* populations have been largely neglected.

In this study, series of *C. picta* populations from eastern Ontario and southwestern Quebec have been analysed to determine the amount of intergradation between *C. p. marginata* and *C. p. picta* based on the shell scute alignment and colour patterns.

Materials and Methods

Two hundred and forty-four specimens of *Chrysemys picta* obtained from nine Canadian localities (Figure 1, Table 1) were examined. The Ste Anne de Bellevue, Quebec, specimens (locality 3), collected during the course of a long-term mark-recapture study, were measured alive; all other specimens were examined preserved and are stored at the University of Montreal, Department of Biology.

Chrysemys picta picta and *Chrysemys picta marginata* have been distinguished on the basis of three main characters: 1) the degree of alignment of the seams separating vertebral scutes with those separating pleural scutes; 2) the width and colour of the anterior borders of the pleural scutes; and 3) the presence or absence of a plastron figure. *Chrysemys p. picta* has seams lying on the same line, light, wide pleural borders and an unmarked plastron. In *C. p. marginata*, the scute seams alternate, the pleural borders are dark and narrow, the plastron is marked with a dark symmetrical central figure.

The method of Hartman (1958) was used to quantify the degree of vertebral and pleural scute seam alignment. This method measures the amount of disalignment in the seams of a specimen, with 100% disalignment representing seams that exactly alternate and 0% disalignment

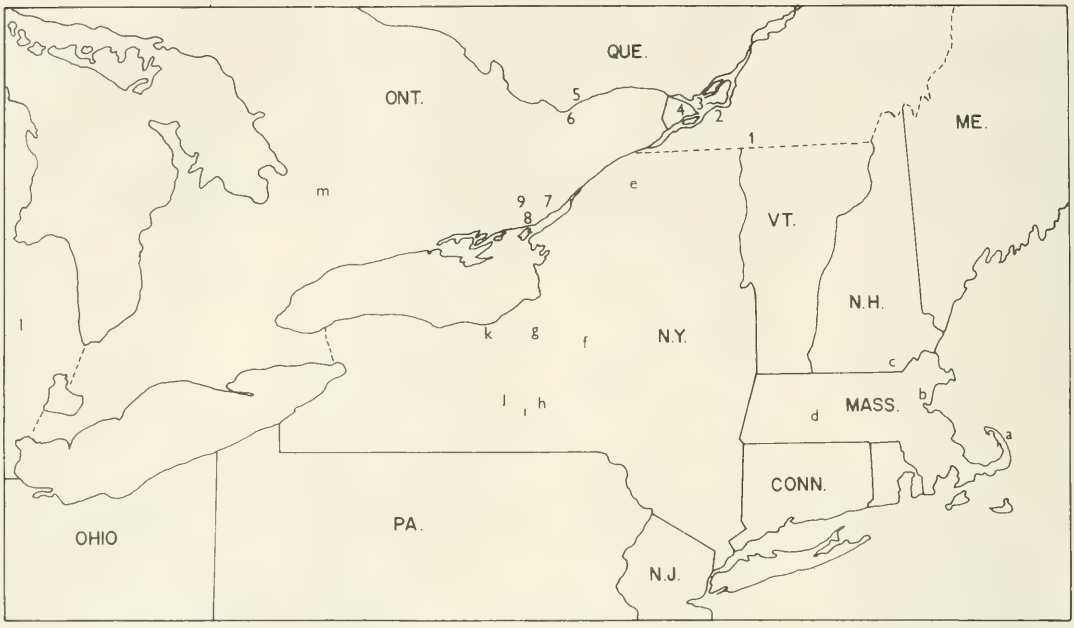

FIGURE 1. Sample localities of *Chrysemys picta*. The numbered localities denote the samples examined as part of this study. The localities represented by letters (a-l) are from Hartman (1958). Locality, m, is from Williams and Crossman (1977). The localities names are given in Figure 5.

describing seams that lie on the same transverse line. The method involves measuring the distance between the anterior, proximal corner of pleural scute two and the posterior proximal corner of the same scute. This distance is denoted as 1A. An imaginary line is then extended along the posterior seam of vertebral two, the distance from where this imaginary line intersects line 1A to the posterior proximal corner of pleural two is then measured. This distance is denoted as 1B. The same measurements are made on the opposite side of the carapace and are denoted as 2A and 2B. The percent disalignment is calculated as,

$$[(1B/1A) + (2B/2A)] \times 100$$

The width of the pleural borders was determined by measuring the anterior border of pleural two on each side of the carapace and averaging these values. All measurements were made using dial calipers accurate to 0.01 mm.

The plastron figures were photographed using black-and-white film and constant lighting conditions. Plastron size (not including bridges) and plastron figure size were determined by using the negative to project a life-size image of the plastron onto graph paper. The intensity (darkness) of the plastron figure relative to the plastron was determined using a Bessler PM2 Colour Analyser (white light setting) and measuring the amount of light falling on a 7.1 mm^2 area. The probe was placed beneath the projected life-size image, on a spot in the anterior and distal corner of the femoral scute, and the meter was nulled. The probe was then placed on the plastron figure in the anterior, proximal corner of the femoral scute and a reading taken. This reading quantifies the intensity of the plastron figure relative to the background intensity of the plastron. Intensity is in arbitrary units on a log scale.

Results

There were significant differences in the average percent disalignment among localities ($F = 10.71$, $p < 0.0001$). A comparison of the sample means presented in Table 1 revealed that only the Pike River sample (locality 3) is significantly different from the other localities (Tukey's W-procedure, *alpha* = 0.01). The overall mean percent disalignment of the remaining eight localities was 80.5%.

A plot of percent disalignment against carapace length revealed that the degree of seam disalignment increased with increasing carapace length (Figure 2). There were no significant differences in the slopes of the least-squares regression lines among localities ($F = 1.35$, $p > 0.22$; $R^2 = 0.095$, $p < 0.001$). As there were significant differences in carapace length among localities ($F = 5.76$, $p < 0.0001$), analysis of covariance was used to adjust for the effect of carapace length.

TABLE 1. Carapace lengths, scute seam disalignments, and border widths, of *Chrysemys picta* from localities in eastern Ontario and southern Quebec. Numbers in parentheses refer to those in Figure 1.

Number: Locality: Latitude and longitude	N	Carapace Length (cm) $\bar{X}$	Seam Disalignment (%) $\bar{X}$	S.D.*	Border Width† (mm) $\bar{X}$	S.D.
Quebec						
(1) Pike River 45°07′N, 73°04′W	19	10.2	62.3	10.4	1.6	0.6
(2) Chateauquay 45°23′N, 73°45′W	34	12.0	75.8	10.7	1.3	0.5
(3) Ste Anne de Bellevue 45°25′N, 73°56′W	62	12.5	80.6	9.5	1.6	0.6
(4) Coteau Landing 45°15′N, 74°13′W	67	10.1	79.2	10.6	1.5	1.4
(5) Wakefield 45°38′N, 75°56′W	8	11.2	82.2	5.7	1.4	0.9
Ontario						
(6) Hazeldean 45°18′N, 75°53′W	12	11.1	80.9	6.4	1.2	0.2
(7) Charleston Lake 44°32′N, 76°00′W	21	12.9	85.2	5.7	1.1	0.5
(8) Opinicon Lake 44°32′N, 76°22′W	11	12.8	87.0	4.8	1.1	0.4
(9) Kingston 44°14′N, 76°30′W	8	14.6	85.0	9.5	1.3	0.5

†The regression coefficient used in adjusting border width was 0.0125 and the means for each locality were adjusted to a carapace length of 11.85 cm.
*S.D. is the standard deviation of the sample.

Adjustment of the mean percent disalignment for each locality to a common carapace length had little effect, with the average difference between adjusted and unadjusted means being about 1%.

The slopes of the least-squares regressions describing the relationship between pleural border width and carapace length were homogeneous among localities ($F = 1.75$, $p > 0.08$; $R^2 = 0.32$, $p < 0.001$). Covariance analysis revealed that border widths (Table 1) were significantly different among localities ($F = 3.72$, $p < 0.001$).

Overall, 90.5% of the specimens had a discernable plastron figure and the presence or absence of a figure was independent of age, sex or locality ($\chi^2 = 4.58$, $p > 0.4$). Table 2 presents the summary statistics, by locality, of plastron area and figure area. Plastron figure area increased in a non-linear manner as plastron area increased

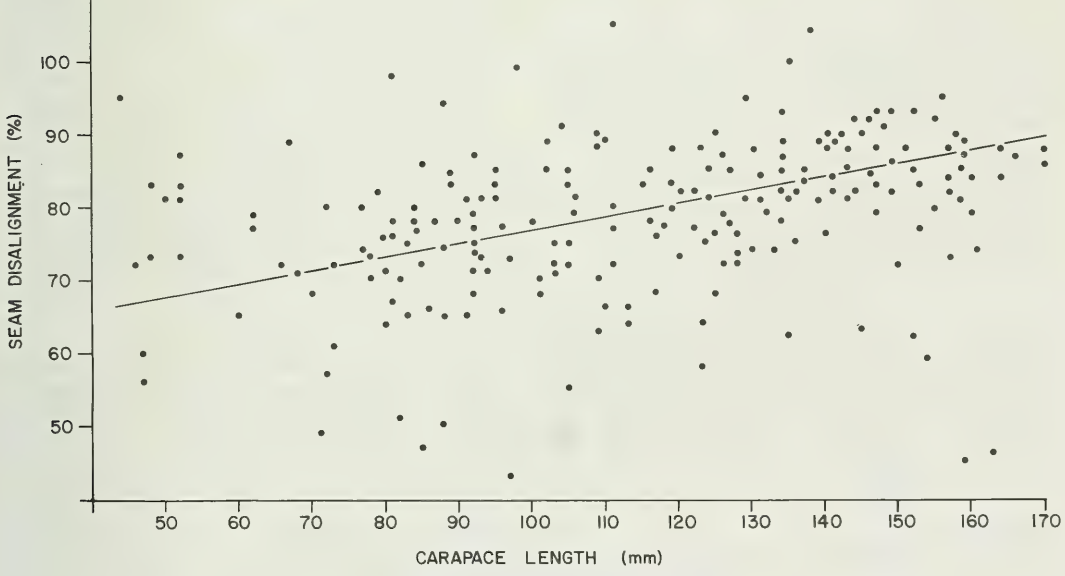

FIGURE 2. The relationship between percent seam disalignment and carapace length in *Chrysemys picta*. The graph is based on all specimens from the 9 localities. The slope of the regression line is 0.11%/ mm and the intercept is 66.2%.

TABLE 2. Description statistics for the plastron size and plastron figure size of *Chrysemys picta* from localities in southern Quebec and eastern Ontario.

Locality	Sex[1]	N[2]	Plastron Area (cm^2) $\bar{X}$	S.D.	Figure Area (cm^2) $\bar{X}$	S.D.
Pike River	M	1	38.4		6.8	
	F	2	75.7	19.6	11.7	
	J	11	24.0	11.3	1.7	1.3
Chateauquay	M	13	63.4	21.3	18.0	3.2
	F	9	72.2	30.6	17.9	14.2
	J	6	15.4	9.6	2.4	2.2
Coteau Landing	M	19	51.2	9.4	11.2	3.1
	F	9	86.7	15.0	24.7	10.2
	J	31	25.2	7.8	3.9	2.2
Wakefield	M	3	69.8		26.5	
	F	3	52.5		14.3	
	J	2	22.1		7.3	
Hazeldean	M	2	62.5		26.5	
	F	2	70.0	10.6	21.7	
	J	5	26.5	10.7	4.7	1.8
Charleston Lake	M	7	63.5	7.9	18.3	3.2
	F	10	74.8	16.9	26.4	8.5
	J	2	27.3		5.9	
Opinicon Lake	M	5	57.3	12.2	19.1	7.4
	F	3	73.1		22.1	
Kingston	M	1	64.1		19.9	
	F	6	85.5	12.7	28.8	7.8

[1]M,F,J: males, females, juveniles.
[2]Number of specimens for which data were obtained.

(Figure 3). The regression model that was found to best describe this relationship (in terms of R^2 improvement) was a quadratic model of the form

$$Y = a_0 + a_1X + a_2X^2,$$

where Y is the figure area and X is the plastron area. The regression coefficients determined for each locality (Table 3) were found to be non-homogeneous ($F = 5.11$, $p < 0.0001$), precluding an analysis of covariance.

The intensity of the plastron figure decreased with increased figure area (Figure 4). A logarithmic regression of the form

$$Y = a + b(\ln X)$$

provided the best empirical description of the relationship. The regression coefficients were homogenous among localities ($F = 0.97$, $p > 0.45$; $R^2 = 0.40$, $p < 0.001$), however covariance analysis established that there were no significant differences in figure intensity among localities ($F = 0.76$, $p > 0.62$).

Discussion

Pough and Pough (1968) found that percent seam disalignment decreased with increasing carapace length in a population of juveniles and adults from Long Island, New York. This was the opposite of the relationship found in the specimens examined during this study (Figure 2). The reasons for this discrepancy are unknown, but it does illustrate a need for a study that monitors seam disalignment in individual turtles as they grow.

The percent seam disalignment results reported in this and other studies are compared in Figure 5. All of the Canadian localities show significantly higher seam disalignments than the samples from New Hampshire and Massachusetts. Among the Canadian and New York localities, only the Pike River population has significantly different average seam disalignment (62.3%), with the other localities having an average seam disalignment of 80.5%.

The "typical" plastron figure of the *Chrysemys picta* examined in this study consists of a band of pigment centered on the mid-line of the plastron. The band is generally less than half the width of the plastron and extends from the anterior portion of the anal scutes to the posterior tips of the gulars. The posterior portion of the figure is generally wider than the anterior part and there are usually only slight extensions of the figure along the scute seams. When the figure covers less of the plastron

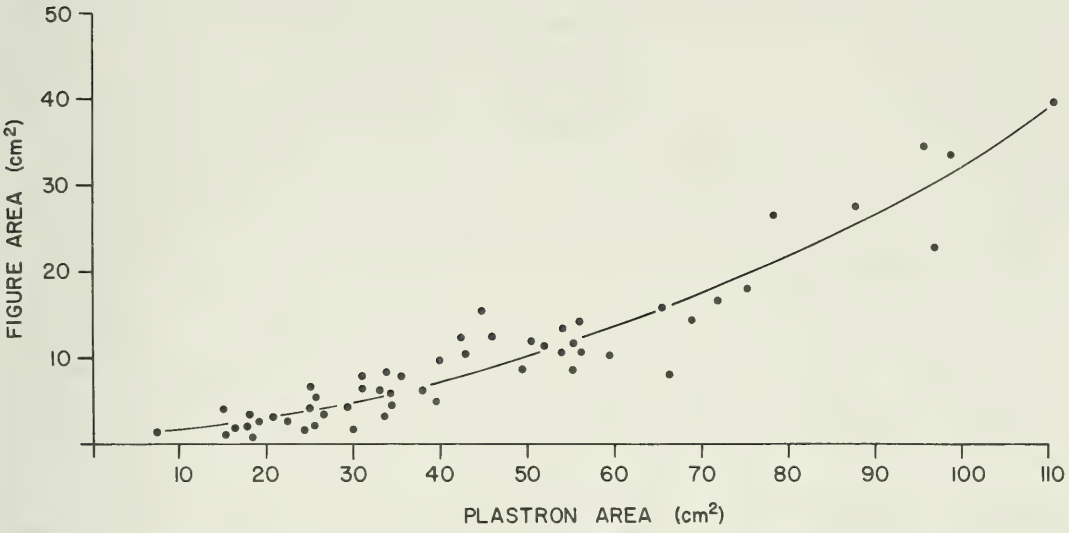

FIGURE 3. The relationship between plastron figure area and plastron area in *Chrysemys picta*. The graph is based on the specimens in the Coteau Landing sample. The coefficients of the model are presented in Table 3.

than described above, it is usual for the anterior portion of the figure to be reduced.

The size of the plastron figure increases at a greater rate as plastron area increases (Figure 3), thus the larger the turtle, the greater proportion of the plastron is covered by the figure. Concomitant with this change is a change in the intensity of the figure colour. The plastron figure tends to become lighter as the figure becomes larger, and approaches the same intensity as the plastron background colour.

Bleakney (1958) postulated a series of events to describe the dispersal of *Chrysemys picta* following the Wisconsin glacial period. He suggested that during the glacial perioid three isolated populations existed: 1) a form much like *C. p. bellii* in the New Mexico area; 2) a southern Mississippi *C. p. dorsalis* form; and 3) a southeastern Atlantic coast form, *C. p. picta*. Following the final retreat of the glaciers all three forms spread northwards. Hybridization occurred where *C. p. bellii* met *C. p. dorsalis* during their northward expansion, creating the form now known as *C. p. marginata* which spread northwards into the central United States in front of the two parent populations. During this time *C. p. picta* was also spreading north along the Atlantic seaboard, but was isolated from *C. p. marginata* by the Appalachian Mountains. Bleakney further postulated that *C. p. marginata* invaded southern New York State via the Mowhawk Valley and Hudson River where it met *C. p. picta* moving up the coast. Further hybridization occurred and this intermediate form colonized the northern New England area and the Canadian Maritime Provinces of New Brunswick and Nova Scotia.

The Pike River population has a significantly lower seam disalignment (62.3%) than the other Canadian and New York State localities. In addition, this population has the widest margin borders and smallest plastron figures (Tables 1 &

TABLE 3. Regression coefficients of the quadratic model ($Y = a_0 + a_aX^2$) describing the relationship between plastron figure (Y) area and plastron area (X) in *Chrysemys picta* from localities in southern Quebec and eastern Ontario

Locality	N	a_0	a_1	a_2	R^2
Pike River	14	- 0.049	0.0574	0.0012	0.83
Chateauquay	28	0.293	0.1105	0.0022	0.91
Coteau Landing	59	1.061	0.0508	0.0023	0.90
Wakefield	8	2.714	0.1537	0.0020	0.86
Hazeldean	9	0.165	0.0432	0.0049	0.97
Charleston Lake	19	1.386	0.1656	0.0020	0.77
Opinicon Lake	8	-36.430	1.3664	-0.0071	0.79
Kingston	7	54.294	-0.9965	0.0080	0.40

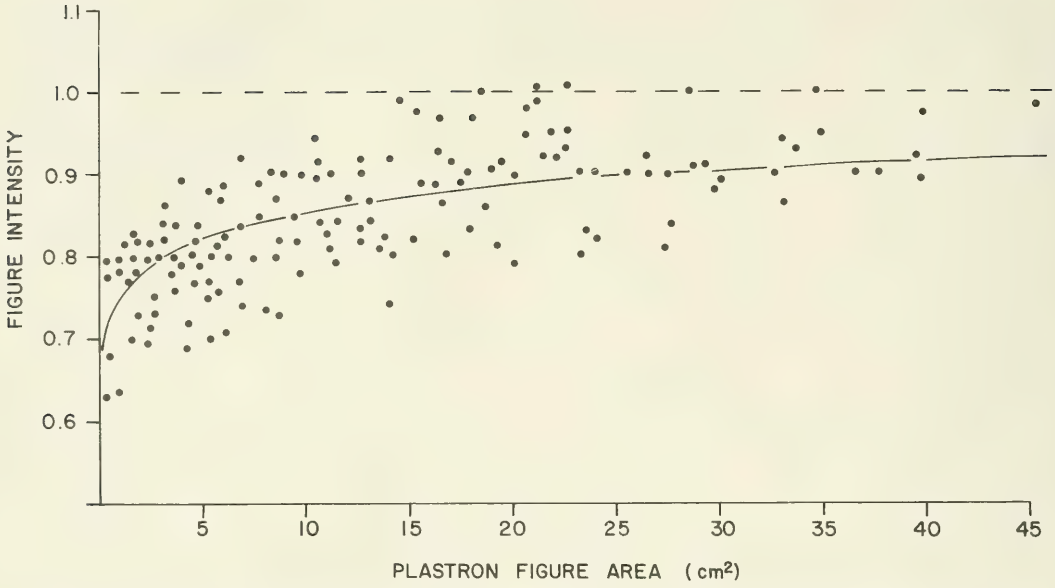

FIGURE 4. The relationship between plastron figure area and figure intensity in *Chrysemys picta* based on all specimens. The coefficients are intercept = 0.75 and slope = 0.43. The dashed line represents the intensity of the plastron background colour. Therefore points below the dashed line represent plastron figures darker than the plastron.

2). Low seam disalignments, wide laminar margins and reduced plastron marking are all *C. p. picta* attributes. the presence of these characterisitcs in the Pike River population suggests the *C. p. picta* influence extends from the south to at least the northern end of Lake Champlain.

Reference to the three Montreal area localities (2,3,4) suggests that the *C. p. picta* influence extends to this region as well. These localities show a greater degree of variation in seam disalignment, tend to have wider scute borders and smaller plastron figures than the localities west of the Montreal region.

If, as postulated by Bleakney, *C. p. marginata* arrived in the region of the New England seaboard via the Mohawk and Hudson Rivers during its postglacial dispersal, and hybridized with *C. p. picta,* it is equally likely that the *C. p. picta* genome may have spread northwest via the Hudson River and Lake Champlain system to the Richelieu and St. Lawrence Rivers. Because of the presence of *C. p. marginata* characteristics in *Chrysemys* populations from New Brunswick and Nova Scotia (Bleakney, 1958) and *C. p. picta* attributes in western Quebec (this study), *Chrysemys* populations in eastern Canada and the northeastern United States should be considered a mixed assemblage showing characteristics of both subspecies. In turn, the breadth of this zone of intergradation calls into question the utility of the idea that *C. p. marginata* is a distinct subspecific entity, rather than simply a central hybrid swarm descended from the three southern subspecies.

Acknowledgments

Specimens at the University of Montreal had been collected by J. Moisiman and J. R. Bider during the course of investigations of Painted Turtles in southern Quebec and eastern Ontario in the late 1950s and are uncatalogued. The Ste-Anne-de-Bellevue locality is on the MacDonald College campus, McGill University, and is the site of long-term mark-release studies by J. R. Bider during the past 30 years. Individuals used for this study were collected during the mid 1970s. I thank the staff of the Biology Department of the University of Montreal and J. R. Bider for making their collections and study animals available to me.

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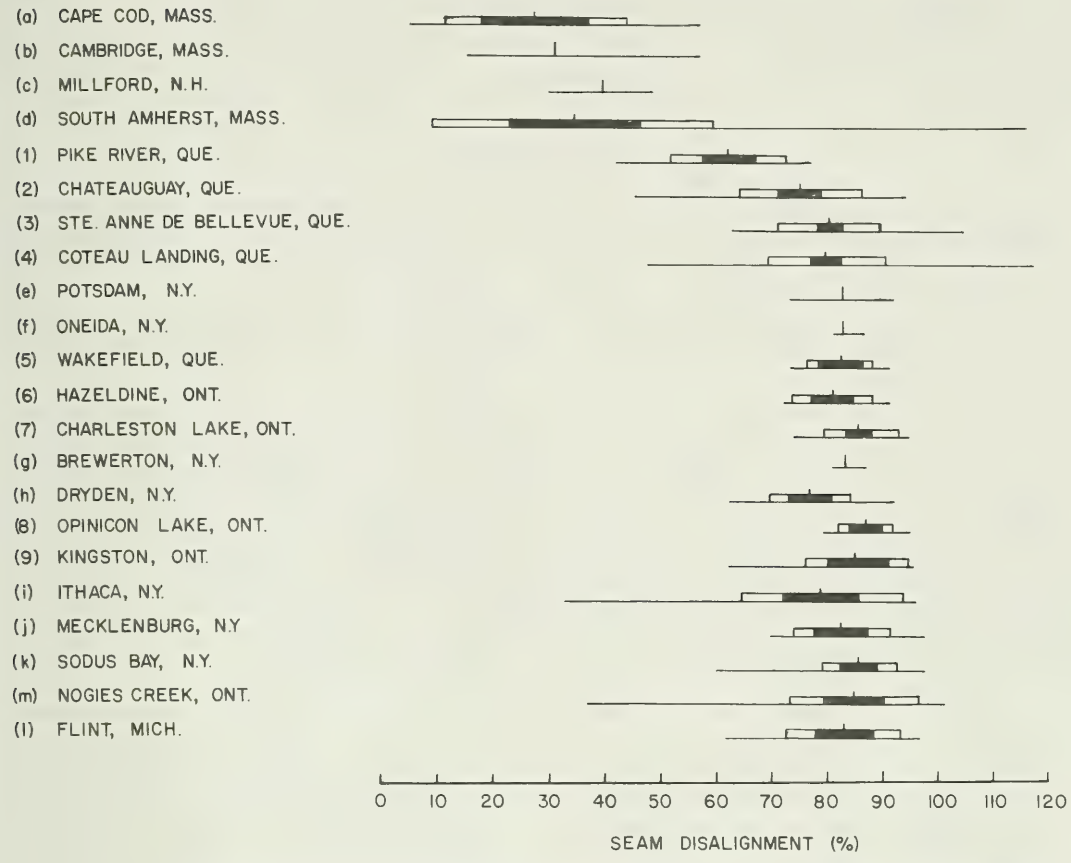

FIGURE 5. Percent seam disalignments for *Chrysemys picta* from localities in southern Canada and the northeastern United States. The numbered localities are those examined as part of the study, the lettered localities (a-l) are from Hartman (1958), and locality m is from Williams and Crossman (1977). The vertical bars denote the mean, the black bars two standard errors of the mean, the open bars the standard deviation, and the horizontal lines represent the range of the samples. (Note: "Hazeldine" = Hazeldean)

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Population Estimates, Nesting Biology, and Habitat Preferences of Interlake, Manitoba, Sandhill Cranes, *Grus canadensis*

SCOTT M. MELVIN[1,2], W. J. DOUGLAS STEPHEN[3], and STANLEY A. TEMPLE[1]

[1]Department of Wildlife Ecology, University of Wisconsin, Madison, Wisconsin 53706
[2]Present address: Massachusetts Division of Fisheries and Wildlife, Field Headquaters, Westborough, Massachusetts 01581
[3]Deceased (formerly of Canadian Wildlife Service, Saskatoon, Saskatchewan).

Melvin, Scott M., W. J. Douglas Stephen, and Stanley A. Temple. 1990. Population estimates, nesting biology, and habitat preferences of Interlake, Manitoba, Sandhill Cranes, *Grus canadensis*. Canadian Field-Naturalist 104(3): 354–361.

We found breeding Sandhill Cranes at 86 sites in the Interlake region of central Manitoba between 1977 and 1980. In 1979 we found 54 pairs in a 4250 km² portion of our study area. This density of 1.3 pairs per 100 km² is the lowest reported for Sandhill Cranes in boreal and arctic North America. Over 400 additional cranes were present as nonbreeders in 1979. Of a sample of 32 nests, 17 occurred on "islands" or raised hummocks dominated by woody vegetation, and 15 occurred in herbaceous emergent vegetation. Mean clutch size was 1.89. Hatching began during the last week of May and continued into June. Forty-seven of 51 (92%) nests occurred in fen muskegs, as did 91 of 106 (86%) observations of crane families with chicks. These percentages were significantly higher than expected based on known acreages of fen and bog muskegs, forested muskegs, and mineral soils in the study area. Fen muskegs may be selected over bog muskegs because of the former's higher productivity. Fen peatlands may be predictors of the distribution and relative abundance of breeding Sandhill Cranes elsewhere in central Canada.

Key Words: Sandhill Cranes, *Grus canadensis*, Manitoba, population estimates, nesting biology, habitat preference, muskeg, peatland, fen.

Research on Sandhill Cranes (*Grus canadensis*) in the Interlake region of Manitoba was initiated in 1977 in conjunction with Whooping Crane (*G. americana*) recovery efforts. The Whooping Crane Recovery Plan (U.S. Dept. of the Interior 1980) calls for the establishment of two new self-sustaining populations of Whooping Cranes geographically separated from the wild population that breeds in Wood Buffalo National Park, Canada, and winters along the Gulf Coast of Texas. Efforts to establish a breeding population of Whooping Cranes in the Rocky Mountain states through cross-fostering with Sandhill Cranes began in 1975 (Drewien and Lewis 1987). Sandhill Cranes in Idaho have accepted and hatched eggs from wild and captive Whooping Cranes, have reared the cross-fostered Whooping Crane chicks as their own, and have remained with the young through their first fall migration and winter and for at least a portion of the return spring migration. Pair formation and breeding, however, have not yet occurred in the Rocky Mountain Whooping Crane population.

As a result of the initial success of the Rocky Mountain cross-fostering experiment, a search began in 1977 for a second population of Sandhill Cranes, in Canada, that could be used to establish a third wild population of Whooping Cranes. Potential areas where reasonable densities of breeding Sandhill Cranes might occur had been identified in Manitoba near The Pas and Grand Rapids (Hildebrand 1974; J. B. Gollop, personal communication), near Sprague (J. B. Gollop, personal communication), and near Ashern, Gypsumville, Hodgson, and Riverton in the Interlake district (J. B. Gollop, personal communication, G. W. Kaiser, personal communication). An aerial reconnaissance of the Interlake in the spring of 1977 revealed a number of pairs of Sandhill Cranes on breeding territories and a limited network of roads and trails that would facilitate access to breeding areas.

The population of Sandhill Cranes breeding in the Interlake was selected for more intensive study, beginning in the summer of 1977. Our objective was to collect data on population size and distribution, breeding biology, and habitat affinities of Sandhill Cranes in the Interlake, concurrent with a colour-marking and radio-tracking study to determine the migration routes and wintering distribution of this population (Melvin 1982; Melvin and Temple 1983).

Study Area

The Interlake region of Manitoba comprises the area lying between Lake Winnipeg on the east and lakes Manitoba and Winnipegosis on the west. Our 8380-km² study area was situated in the central

part of the Interlake, 50 to 120 km north-northwest of Winnipeg (51°30′N, 98°00′W). It was roughly bounded to the west by Route 6 and Lake St. Martin, to the north by the Dauphin River and Lake Winnipeg, to the east by Lake Winnipeg, and to the south by an arbitrary line running from Ashern and Fisher Branch east to the head of Washow Bay on Lake Winnipeg (Figure 1).

The Interlake is a sparsely populated area at the southern edge of the Boreal Forest region (Rowe 1959) and at the northeastern fringe of Manitoba's agricultural region. The climate is subhumid and continental, with long cold winters and short warm summers. Annual precipitation is about 51 cm, 70% of which falls as rain between April and October. The transition from winter to summer is abrupt and generally occurs in April.

The topography of the Interlake is one of low relief, with calcareous glacial tills and occasional lacustrine deposits overlying limestone and dolomitic bedrock (Mills and Smith 1971; Smith et al. 1975). Narrow drumlins, glacial striations, and strand lines generally running north to south act as impediments to surface drainage and have created a low ridge and swale topography. The surface is level to gently sloping and is poorly drained; local flooding often occurs during the spring thaw and after heavy rains. Peat accumulation and beaver activity also act to impede surface drainage. The resulting landscape is a mosaic of low forested ridges interspersed with low-lying, poorly-drained, forested muskegs of Black Spruce (*Picea mariana*) and Tamarack (*Larix laricina*), open bog and fen muskegs, and small intermittent lakes.

Climate and soil conditions have resulted in vegetation generally characteristic of the southern part of the Boreal Forest region (Rowe 1959). Trembling Aspen (*Populus tremuloides*), is common in the southern part of the study area and represents an intermediate successional stage after fire or logging. Limited cereal grain cultivation, hayfields, and livestock grazing occur along the western and southern edges of the study area. Elsewhere the forest vegetation is dominated by Black and White Spruce (*P. glauca*) mixed with poplar (*Populus* spp.), and White Birch (*Betula papyrifera*), with Jack Pine (*Pinus banksiana*), occurring on sandy, well-drained ridges. Muskeg vegetation characteristic of low, poorly-drained areas includes Black Spruce, Tamarack, sphagnum moss (*Sphagnum* spp.), Dwarf Birch (*B. glandulosa*), ericaceous shrubs, and a variety of sedges, grasses and rushes.

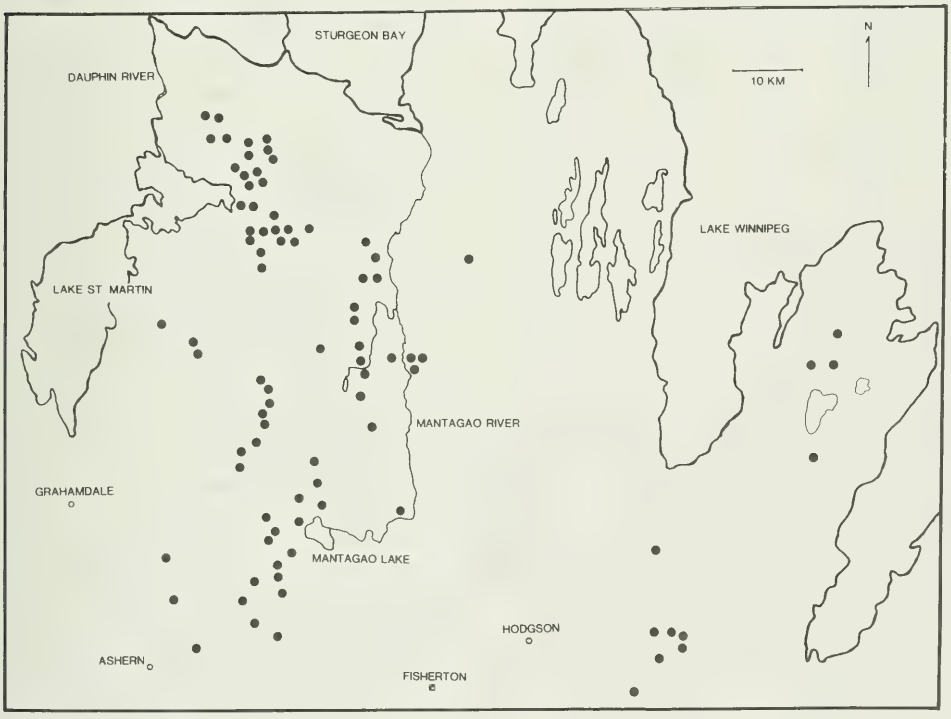

FIGURE 1. Distribution of 86 Sandhill Crane breeding territories in the Interlake, Manitoba study area, 1977-79.

Methods

Field work was conducted in July and August 1977, April through August 1978, April through July 1979, and in May and July 1980. A limited network of dirt roads restricted our ground access to muskegs used by breeding Sandhill Cranes. Ground travel to breeding muskegs was either by foot or all-terrain vehicles and was restricted to areas within about 3 km of existing roads. Access to Sandhill Crane breeding territories was, therefore, primarily by aircraft. Fixed-wing aircraft on floats were used for reconnaissance and crane counts throughout the study area. Helicopters were used in searching for nests and crane families with chicks and for some visits to nest sites.

Topographic maps (1:50 000 or 1:250 000) were the principal means of navigation from aircraft and provided overviews of the Interlake study area. LANDSAT satellite imagery at scale 1:1 000 000 was used to supplement navigation from the air and to correlate topographic features with vegetative features. Aerial photographs at scale 1:63 360 and uncontrolled photo mosaics prepared by the province of Manitoba at approximately 1:31 680 were used to plot detailed ground locations of adult and immature cranes and nests.

Searches for nests began at sites identified as potential breeding territories by the presence of paired cranes previously noted from the air or seen or heard from the ground. We also searched areas that appeared similar to sites where nests had already been found. We collected information on the dominant vegetation at the nest site, water depth, distance to nearest upland forest, and clutch size. Some nests were later revisited to determine hatching dates.

We matched locations of crane nests and observations of crane chicks with soil types using Manitoba Soil Survey reports (Pratt et al. 1961; Mills and Smith 1971; Smith et al. 1975). We classified soil types as either mineral soil or one of three types of muskeg (organic soil): fen, bog, or forested muskeg (Jeglum et al. 1974; Smith et al. 1975; Tarnocai 1980). Our use of the term muskeg follows Stanek (1977) and collectively describes a variety of open to forested boreal peatlands characterized by poorly-drained organic soils. Fen muskegs are minerotrophic peatlands underlain primarily by herbaceous peats that are moderately well decomposed and range from medium acid to mildly alkaline (Smith et al. 1975). Dominant vegetation of Interlake fens includes sedges (*Carex* spp.), grasses, bulrushes (*Scirpus* spp.), Cattail (*Typha latifolia*), willows (*Salix* spp.), and Dwarf Birch. Scattered Black Spruce and Tamarack are also present. Bog muskegs are ombrotrophic peatlands underlain primarily by *Sphagnum* peats that are poorly decomposed and slightly to extremely acidic. Dominant vegetation of Interlake bog muskegs includes *Sphagnum* mosses, ericaceous shrubs, and stunted Black Spruce and Tamarack. Forested muskegs are minerotrophic peatlands underlain primarily by woody peats and some *Sphagnum* peats that are moderately decomposed and slightly to moderately acidic. Dominant vegetation is Black Spruce with an understory of ericaceous shrubs and *Sphagnum* and other mosses.

Results and Discussion

Nesting Biology

Sandhill Cranes were already present on territories by 21 April 1978 and 20 April 1979, the dates of our earliest aerial reconnaissances. Backdating from hatching dates in 1978-80 indicated the peak period of egg laying occurred during the last week in April and early May.

We found nine nests in 1978, 28 in 1979, and 11 in 1980. Data were also available on locations of three nests reported in 1975 (C. Dixon, personal communication). In 1978 six of nine nests were located from the ground and three were located by helicopter. In 1979, 25 nests were located during eight hours of helicopter search, and the remaining three were found during ground searches. We found 11 nests in 8.8 hours on 31 May 1980 during a helicopter survey of selected muskegs, but only seven of these contained eggs. We found only a portion of the nests present on the study area each year, as crane chicks were often seen in muskegs where nests had not been sought or had not been found. During our helicopter searches in 1979 and 1980 we located crane nests at a rate of 2.1 nests/h (36 nests in 16.8 h). Howard (1977) used helicopters to locate Sandhill Crane nests in central Wisconsin at rates of 1.1 nests/h in 1974 and 3.0 nests/h in 1975.

The mean clutch size of 46 nests with eggs found from 1978 to 1980 was 1.89. Seven contained one egg, 37 contained two eggs, and two contained three eggs. Hatching began during the last week of May and continued into June. In 1978, four of nine (44%) nests hatched one or both eggs between 27 and 30 May. Three active nests had not hatched by 30 May, but were not checked thereafter. Two nests containing eggs were abandoned prior to hatching. In 1979, 5 of 27 (18%) nests with eggs hatched one or both eggs during the period 31 May-6 June. A 28th nest contained no eggs when observed on 29 May. The contents of 22 nests had not yet hatched when last visited between 29 May and 6 June. Of 11 nests located on 31 May 1980, one was empty, three contained one egg, five contained two eggs, and two contained three eggs.

At least three other nests had already hatched by 31 May, as evidenced by observations of one family with two chicks and two families with one chick each.

Active nests were found no closer than 0.6 km from each other. Seldom was more than one nest found in the same muskeg unless there was some sort of visual barrier between nest sites. Often nests were located within indentations or "bays" of the muskegs. All nests were separated from upland forest by an expanse of wetland. Seven nests averaged 80 m (range = 40-106 m) from the edge of the muskeg. The mean diameter of seven nests was 0.8 m (range = 0.5-1.0 m). Water depths at seven nests ranged between 10 and 50 cm, with a mean of 20 cm.

Population Estimates

We identified Sandhill Crane breeding territories with nests, flightless chicks, or both at 86 separate sites between 1977 and 1980 (Figure 1). Of these, 75 (87%) were in the western half of our study area. This was an area of 4250 km^2 where we concentrated our surveys, west of a line running north-south about 5 km east of the Mantagao River. In 1979, the year we conducted our most intensive surveys, we found 54 breeding pairs in this area, a density of 1.3 pairs per 100 km^2, plus 11 additional pairs in the eastern half of the study area. The densest concentration of territories was 21 pairs in 280 km^2 (7.5 pairs per 100 km^2) in a series of muskegs near the northeast end of Lake St. Martin.

Our density estimates are comparable to those reported by Carlisle (1979) in central Alberta, but are much lower than estimates for other populations of Sandhill Cranes in boreal or arctic North America (Table 1). Tundra habitats in Canada and Alaska (Walkinshaw 1965; Boise 1977) and southern boreal habitat in northern Michigan (Taylor 1977) both apparently support higher densities of breeding Sandhill Cranes than do boreal habitats in central Manitoba.

We are uncertain how the availability or productivity of wetlands used by breeding cranes in the Interlake compares to other crane habitat in arctic and boreal North America, and how this may relate to the relatively low population densities we found. Our data do not allow us to speculate whether the population of breeding Sandhill Cranes in the Interlake is at or below carrying capacity. We have suggested that overharvest of Interlake cranes may occur during fall hunting, particularly in North Dakota (Melvin and Temple 1983).

We estimate that over 400 non-breeding Sandhill Cranes were also present on the study area during the summer of 1979. At least 370 cranes in flocks of 15 to 220 were observed during 27 June - 14 July 1979, particularly in cultivated fields and wetlands along the southern fringes of the breeding muskegs-forest complex near Sleeve Lake, Fisher Branch, and Sylvan. Other flocks of three to eight non-breeders were seen scattered throughout muskegs in the study area during the summer, but we have no estimate of their total numbers. Based on sightings in previous years, we suspected that additional flocks of non-breeders frequented agricultural areas along the west side of Lake St. Martin during June and July 1979. We observed 50 cranes near Sandy Bay on Lake St. Martin on 26 July 1978, and a flock of 200 was reported from a site 7 km west of Sandy Bay on 12 July 1975 (C. Dixon, personal communication). We cannot estimate what percentages of these non-breeders originated within the study area or immigrated from other breeding areas in central Manitoba. Presumably many of these birds were 1, 2, or 3-year-olds that had not yet paired.

Habitat Use

We found nests in two general types of sites in muskegs. Of a sample of 32 nests for which we collected site data, 17 were on "islands" or raised hummocks dominated by woody vegetation, and 15 were in stands of herbaceous emergent

TABLE 1. Density estimates of breeding Sandhill Cranes in boreal and subarctic regions of North America.

Location	Dates	Density (pairs/ 100 km^2)	Total pairs/ area surveyed (km^2)	Source
Interlake, Manitoba	1979	1.3	54/4250	this paper
Central Alberta	1976	4.7	7/150	Carlisle (1979)
	1977	2.4	8/340	
Banks Island, Northwest Territories	1964	17.0	8/47	Walkinshaw (1965)
Upper Peninsula, Michigan	1977	23.0	130/565	Taylor (1977)
Yukon-Kuskokwim Delta, Alaska	1975	52.9	9/17	Boise (1977)
	1976	77.8	21/27	

vegetation. Island/hummock nests were generally at sites dominated by Dwarf Birch, willow, and honeysuckle (*Lonicera* sp.) and variable numbers of live or dead Tamarack and Black Spruce. These nests were usually built on hummocks of moss in clumps of Dwarf Birch or willow, and were constructed primarily of twigs of Dwarf Birch or willow and often lined with pieces of sedge or bulrush (Figures 2, 3). In contrast, nests in emergent vegetation (Figure 4) were generally located at wetter sites, in stands of sedges, bulrushes, and, in two instances, cattails. These nests were mounds of vegetation built in such a way as to elevate the eggs above the water level; thus, they often contained more nesting material than nests built on islands or hummocks.

Of 51 crane nests found in our study area, 47 (92%) occurred in fen muskegs (Table 2). This proportion of occurrence was significantly higher than expected based on the known areas of fen and bog muskegs, forested peatlands, and mineral soils we surveyed in the study area ($\chi^2 = 228$, $p < 0.01$). Four different complexes of organic soils accounted for all of the 47 nests found in fen muskegs (Table 3). These four — Crane, Stead, Cayer, and Macawber — comprised less than 15% of the study area and only 34% of the total muskeg acreage, yet held 92% of all nests found and 96% of all nests found in muskegs. Similarly, 91 of 106 (86%) observations of crane families with chicks, significantly more than expected ($\chi^2 = 383$, $p < 0.01$), occurred in fen muskegs (Table 2). The same four organic soil complexes characterized all of the fens where crane chicks occurred (Table 3).

Only two nests were found in bog muskegs, although bogs comprised 22% of the study area (Table 2) and 57% of the total open muskeg acreage (Table 3). Six observations of crane chicks occurred in bog muskegs, characterized by the Julius, Molson, and Kilkenny soil complexes (Table 3).

Only two crane nests were found on sites characterized by mineral soils (Table 2). One of these was in a roadside ditch adjacent to an improved pasture and was considered atypical. The soil at the other site was composed of 60% poorly-drained loam with a peat surface layer and 40% Crane fen peat complex.

Only 9 of 106 (8%) observations of crane families with unfledged chicks were at upland sites with mineral soils (Table 2). Five of these observations occurred in hayfields where the hay was standing or freshly cut. Two families with chicks were observed foraging in openings on a low sand and gravel ridge along a dirt road right-of-way. An eighth family was observed at a burned-over forest site, and the ninth observation occurred in open Jack Pine forest.

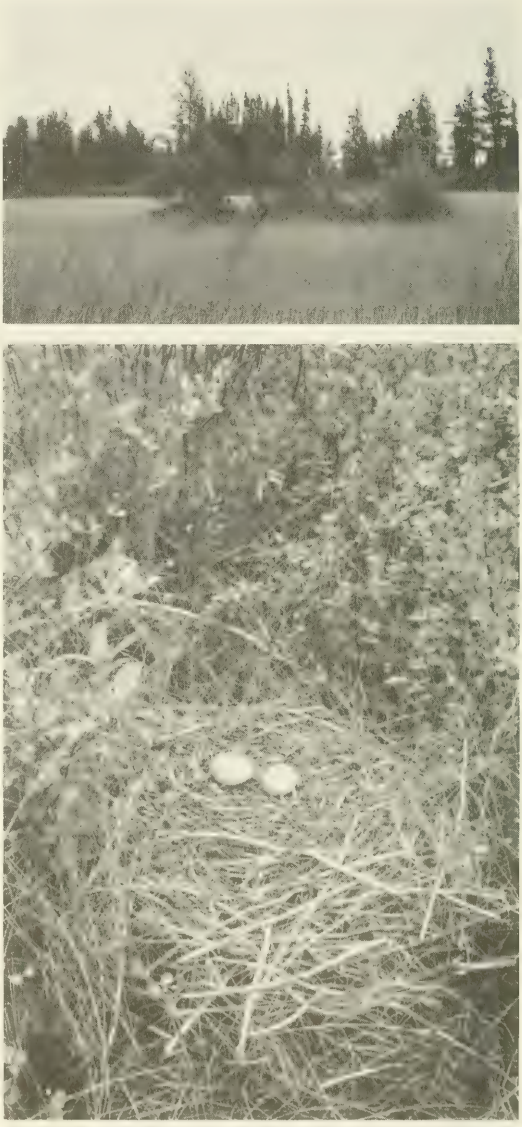

FIGURE 2. Wooded "island" dominated by Honeysuckle and Tamarack used for nesting by Sandhill Cranes in a fen muskeg in the Interlake, Manitoba (top), and nest at this site, constructed primarily of twigs (bottom).

No observations of crane nests or chicks were recorded in forested muskegs (Table 2). These included the Baynham, Bradbury, Grindstone, Janora, Okno, and Rat River organic soil complexes, and a portion of the Deep Peat complex, which together comprised about 5% of

FIGURE 3. Interlake, Manitoba Sandhill Crane nest at hummock site dominated by willow.

FIGURE 4. Interlake, Manitoba Sandhill Crane nest in emergent vegetation dominated by bulrush in a fen muskeg.

the study area. These muskegs are forested with Black Spruce, sometimes in dense stands, with an understory of ericaceous shrubs. This forested aspect probably precluded cranes from using these areas.

Our observations indicated that Sandhill Cranes in the Interlake used open muskegs (fens and bogs) more commonly than forested muskegs or forested uplands for nesting and rearing young, and that fens were selected much more frequently than bogs. Upland sites used by cranes with chicks were considered extensions of breeding territories, and we assumed that those families had originated in nearby open muskegs suitable for breeding.

Why breeding cranes in the Interlake select fens rather than bogs is unclear. It may be that the emergent vegetation characteristic of fens is preferable to the woody vegetation found in bogs. However, Sandhill Cranes reportedly utilize bogs more extensively in other parts of their range. Tebbel (1981) stated that Sandhill Cranes nesting in the Algoma district of central Ontario utilized bogs and fens (Jeglum et al. 1974) about equally, and did not show a marked preference for either type. He found that crane nests occurred commonly in conjunction with sphagnum moss and Leatherleaf (*Chamaedaphne calyculata*), and suggested that the sphagnum was important as a base for the nest, and that Leatherleaf provided concealment and served as a visual barrier for the incubating birds. Cranes in the Upper Peninsula of Michigan use bogs extensively for nesting (Taylor 1976), although fens may be limited in their occurrence in this region (Tebbel 1981: 31). In describing nine sites used by breeding Sandhill Cranes in the southern Hudson Bay Lowland, Ontario, Riley (1982) reported no apparent preference for bogs or fens, describing instead a preference for open peatlands patterned with open graminoid, open low shrub, or treed low shrub phases (Jeglum et al. 1974).

It may be that fen peatlands are selected by Interlake cranes for nesting and brood-rearing because they are more productive and support a more diverse plant community than do bogs. Whether the minerotrophic conditions of fens relative to bogs in the Interlake result in increased abundance or quality of food for cranes is uncertain. Walkinshaw (1949) reported that cranes nesting in acid (pH 4.5-5.0) wetlands of northern Michigan and muskegs of central Alberta more often left nesting wetlands to walk or fly to feed at upland sites than did cranes in more alkaline wetlands of Idaho, Oregon, and southern Michigan (pH up to 7.6). As Interlake crane families are generally unable to move to upland agricultural areas to feed until August, after their

TABLE 2. Occurrences of Sandhill Crane nests and chicks relative to soil and muskeg types.

Soil and wetland type	Km^2 (% total)	Number of crane nests (%)	Number of observations of chicks (%)
Organic soil			
Fen muskeg	1364.4 (16)	47 (92)	91 (86)
Bog muskeg	1827.8 (22)	2 (4)	6 (6)
Forested muskeg	411.3 (5)	0 (0)	0 (0)
Mineral soil	4776.7 (57)	2 (4)	9 (8)
Total	8380.2 (100)	51 (100)	106 (100)

TABLE 3. Occurrences of Sandhill Crane nests and flightless chicks in fen and bog muskegs and their associated soil complexes in the Interlake, Manitoba.

Muskeg Type	Soil complex	Km^2 (%)		Number of nests observed (%)		Number of observations of chicks (%)	
Fen	Crane	245.0	(7.7)	26	(53)	39[c]	(40)
	Cayer	507.9	(15.9)	6[d]	(12)	22[e]	(23)
	Stead	421.6	(13.2)	13	(27)	20	(21)
	Macawber	53.1	(1.7)	2	(4)	10	(10)
	Other fen complexes[a]	136.8	(4.3)	0	(0)	0	(0)
Bog	Julius	898.2	(28.1)	1	(2)	4[f]	(4)
	Molson	796.7	(25.0)	1	(2)	1	(1)
	Kilkenny	68.1	(2.1)	0	(0)	1	(1)
	Other bog complexes[b]	64.8	(2.0)	0	(0)	0	(0)
	Total	3192.2	(100)	49	(100)	97	(100)

[a]Includes Kircro complex (Smith et al. 1975); Chatfield, Shallow Peat, and Deep Peat complexes (Pratt et al. 1961).
[b]Includes Sand River, Sproule, Denbeigh complexes (Smith et al. 1975); Deep Peat complex (Pratt et al. 1961).
[c]Includes one observation in 80% Crane – 20% Kilkenny complex, and one observation in 60% Crane — 40% Kilkenny complex.
[d]Includes three nests in 70% Cayer — 30% Molson complex.
[e]Includes 10 observations in 70% Cayer — 30% Molson complex.
[f]Includes one observation in 50% Julius — 50% Stead complex.

chicks can fly, their choice of productive wetlands for nesting and chick-rearing may be important in meeting the nutritional requirements of both adults and young.

Fen peats — particularly the Crane, Stead, and Cayer complexes — may be predictors of the distribution and relative abundance of breeding Sandhill Cranes in other parts of Manitoba and elsewhere in central Canada. Hildebrand (1974) reported that 61 of 76 (80%) observations of Sandhill Cranes during the summers of 1972 and 1973 near The Pas, Manitoba, occurred on sedge fens. No data were given, however, on the availability of bog muskegs in that area, about 180 km northwest of our Interlake study site.

Walkinshaw (1949) described Sandhill Crane nesting habitat at Fawcett, Alberta, as chains of open muskeg vegetated with moss, sedges, grasses, and Dwarf Birch. Carlisle (1979) described wetlands used by nesting Sandhill Cranes in central Alberta, between the Athabasca and Pembina Rivers, as open sedge marshes dominated by four species of *Carex*, sphagnum moss, Buckbean (*Menyanthes trifoliata*), Marsh Cinquefoil (*Potentilla palustris*), horsetail (*Equisetum* spp.), Bog Rosemary (*Andromeda polifolia*), Bog Willow (*Salix pedicellaris*), and Swamp Birch (*Betula pumila*). These descriptions of wetlands suggest that they are similar to the fen muskegs used by nesting Sandhill Cranes in the Interlake.

Potential For Establishing a Whooping Crane Population

Our results suggest that in several ways the Interlake region of Manitoba is a suitable area for cross-fostering Whooping Cranes. It is on the edge of the historical breeding range of the Whooping Crane as described by Allen (1952), and it still contains abundant, relatively secure wetlands. It supports a number of experienced breeding Sandhill Cranes that could serve as foster parents. It is situated within reasonable proximity to a commercial airport to facilitate transport of eggs.

Our concurrent radio-tracking and colour-marking studies determined that Interlake Sandhill Cranes migrate through the Central Flyway to winter in counties on or near the Texas Gulf Coast (Melvin 1982; Melvin and Temple 1983), including at the Aransas National Wildlife Refuge, the wintering area for most of the Whooping Cranes that nest in Wood Buffalo National Park in Canada. Thus, the winter distribution of the Interlake population is not geographically isolated from existing Whooping Crane populations. This reduces, at least for the present, the suitability of the Interlake region of Manitoba as a potential site for establishing a new population of Whooping Cranes.

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Killer Whales, *Orcinus orca,* Photo-identified in Prince William Sound, Alaska, 1976 through 1987

S. LEATHERWOOD[1], C. O. MATKIN[2], J. D. HALL[3] and G. M. ELLIS[4]

[1]Department of Birds and Mammals, San Diego Natural History Museum, P.O. Box 1390, San Diego, California, California 92112.
[2]North Gulf Oceanic Society, P.O. Box 15244, Homer, Alaska 99603.
[3]Coastal and Offshore Pacific Corporation, Box 31554, 225 Yguacio Valley Road, Suite M-1, Walnut Creek, California 94598.
[4]West Coast Whale Research Foundation, 1040 West Georgia St., Vancouver, British Columbia V6E 4H1.

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Individual Killer Whales, *Orcinus orca*, were identified from photographs taken incidental to other research (1976-1983) or during intensive studies of the species (1984-1987) in Prince William Sound (PWS), Alaska. The 232 identified animals were grouped into pods, based on observed associations, and assigned to the following conservatively defined age/sex categories: adult males (52, 22.41%), adult females (22, 9.48%), calves born 1986 or 1987 (9, 3.9%) or "immatures/others" of both sexes (149, 64.22%). Because of imprecision, this last category may include some adult females, as an animal was only classified as adult female if it was closely associated with a calf, and some recently matured adult males. Age/sex composition in PWS is similar to that noted for other areas of the eastern North Pacific and for Iceland, but caution is indicated in using such data. There were at least 13 births in PWS from 1985 through 1987. In 1984, calves were grouped with "juveniles". The 4 newborn calves first detected in 1985 are now classified as "immatures/others". The combined mortality rate of 1.9% in three pods (AB, AE, AI) is similar to that in British Columbia and Washington (1.7 percent), while that in AB pod (7.4 percent) is significantly higher. Members of AB pod have been interfering with a longline fishery for Sablefish (Blackcod), *Anoplopoma fimbrica*, since 1985. At least 10 (possibly 14) members of AB pod were reportedly wounded by gunshot between late 1984 and fall 1986, some apparently fatally. There were no new bullet wounds detected in 1987. Although no carcasses were found, from 1985 to 1987, there were apparently 7 deaths in AB pod, 2 in AE pod, and one each in AK and AN pods, leaving a documented minimum population of 221 whales in PWS by the end of the 1987 season.

Key Words: Killer Whales, *Orcinus orca,* Alaska, population size, fishery conflicts, Sablefish, Blackcod, *Anoplopoma fimbrica.*

Population studies of Killer Whales, *Orcinus orca*, have been carried out off British Columbia since 1973 (e.g., M. A. Bigg, I. B. MacAskie, and G. Ellis. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island, with comments on management. Unpublished manuscript, Arctic Biological Station, Ste Anne de Bellevue, Quebec, 21 pp; Bigg et al. 1983; Bigg 1982), off Washington since 1976 (e.g., Chandler et al. 1976; Balcomb 1978; Balcomb et al. 1980, 1982), off Argentina since 1975 (Lopez and Lopez 1985), off Norway since 1983 (Lyrholm 1988; Lien et al. 1988) and off Iceland since 1981 (Lyrholm et al. 1987; Sigurjonsson et al. 1988). All these studies have been based primarily on photographic identification of Killer Whales from natural marks visible on high resolution photographs of the dorsal fin and dorsal saddle and of other distinctive features. In the British Columbia and Washington study areas, most individuals in the population(s) are believed to have been identified and their associations into pods (groups of individuals with long-term associations) determined. This has made long-term monitoring of population parameters and social behaviour possible.

Background

From 1976 through 1983, incidental to their primary activities, various marine researchers working in southern Alaska logged sightings of groups of Killer Whales and photographed individual animals. The resulting photographs varied in format, perspective and quality; nevertheless, following procedures in practice elsewhere since 1973 (Bigg et al. 1976 unpublished: cited above; Bigg et al. 1986), distinctively marked individuals were identified (Leatherwood et al. 1984; Matkin et al. 1985; von Ziegesar et al. 1986).

In 1984, a study of Killer Whales was begun in portions of southern Alaska. Almost all activities focused in Prince William Sound (PWS) and southeast Alaska (SEA) (Figure 1), but searches were also conducted in Shelikof Strait on 3 days. High quality photographs, including the best of those taken before 1984, were used to identify individual animals. The goals of the study were to determine size and composition of the Killer Whale population(s). Based on the field season from mid-April to late September 1984, a minimum of 286 whales was photo-identified, including at least 173 from PWS, 96 from SEA and 17 from Shelikof

FIGURE 1. The three regions of southern Alaska where Killer Whales were studied in 1984 (inset) and a detail of Prince William Sound, where Killer Whales were identified form photographs taken 1976 through 1987.

Strait. Of these, 256 were assigned to pods (Leatherwood et al. 1984). Photographs of 238 individuals were of sufficiently high quality to be reproduced in a catalogue of Killer Whales photo-identified in PWS and SEA through 1984 (Ellis 1984)[1]. Repeat sightings of identifiable individuals in PWS from 1977 through 1984 were summarized elsewhere (Leatherwood et al. 1984; Matkin et al. 1985; von Ziegesar et al. 1986).

Work in SEA and Shelikof Strait was discontinued after 1984; however, research in PWS was continued through 1987, albeit on a much reduced scale (Matkin et al. 1985, 1986, 1987; Matkin 1986, 1988; Hall and Cornell 1986; von Ziegesar et al. 1986). An updated catalogue depicting 268 animals photo-identified in PWS and SEA from 1976 through 1986 was published (Ellis 1987).

This paper reports results of all photo-identification efforts in PWS from 1976 through 1987 and discusses those results in the context of other photo-identification studies of this species.

Materials and Methods

Photo-identification

Except for opportunistic photographs taken prior to 1984, all photographs used in this study were

[1]An additional pod of 19 animals (designated as AR in Alaska and as R in British Columbia) was not included in this catalogue, as only 3 of its members were positively identified in Alaska in 1984 and the entire pod had already been catalogued in British Columbia (Bigg et al. 1987).

taken, processed and analyzed using techniques for identification of Killer Whales which have evolved over the last 15 years (Bigg et al. 1976, unpublished: cited above; Bigg et al. 1986). As they are described in detail elsewhere (Bigg 1982; Leatherwood et al. 1984; Bigg et al. 1986; Lyrholm et al. 1987; Sigurjonsson et al. 1988), the techniques are only summarized here.

Killer Whale groups were approached to within 30 m or less and photographed from the left side, at right angles to the dorsal fin, using a motor-driven Nikon FM-2 camera with a fixed-focal-length Nikon 300 mm f 4.5 lens and Kodak Tri X or Ilford HP5 film exposed at ASA 1600. Exposed film was push-processed using Edwal FG-7 fine grain developer with a 9% Sodium Sulphite solution or processed using standard techniques with Acufine developer. A contact sheet of each roll was prepared and filed with the negatives and associated data sheets.

Developed negatives were examined under a Wild M5 stereo-microscope with 8 power eyepieces, affording 4.8 to 40.0 power magnification (9.6 power was used most commonly). Field notes accompanying film from a given encounter were used to help determine the pod(s) involved and to ascertain details of pod structure and individual associations.

Pod Designation

Each pod and its members were provisionally referred to as "residents" or "transients", following terminology used by investigators in British Columbia and Washington to refer to two categories of Killer Whales they found to differ consistently in various morphological and behavioral characteristics (Bigg 1982; Bigg et al. 1985, 1987).

In this study, "resident"-type animals were assigned to pods after they had been encountered repeatedly in close association over the length of the 1984 field season. In addition, some new animals were grouped as "possible new pod" by deducting previously defined pods from large aggregations. These groups were subsequently designated as a pod only if they were seen together again with no other pods present. Because most were encountered only once during the study period, groups of "transient"-type animals were assigned to pods according to their associations at the time of the first encounter.

Pods were designated alphabetically, using two letters, A to indicate Alaska and A to Z to distinguish pods; individuals were designated numerically, in ascending order as they were photoidentified.

Age/Sex Classification

Animals were assigned to age/sex categories using the following characteristics, definitions and assumptions (see Figure 2):

Adult male — by the presence of a dorsal fin with the dimorphic shape and relative proportions assumed elsewhere to indicate a sexually mature male (M. A. Bigg, Pacific Biological Station, Nanaimo; G. M. Ellis, unpublished data). Sex was sometimes confirmed by direct observation of the genital region.

Adult female — by consistent close association with a newborn calf (calf-of-the-season), which in Pacific Killer Whales are about 2.75 m at birth (Nishiwaki and Handa 1958), or a yearling (through age 2). Sex was sometimes confirmed by direct observation of the genital region.

Calf — from birth until completion of the second year of life, by which time it is presumed weaned (Heyning 1987). In 1986 and 1987, classifications of animals as calves were based on the fact the animal was very small and had not been identified in previous years; such classifications often were supported by the small animal's close association with a particular adult, its tendency to expose its head beyond the eye level when surfacing and an orange tint to its "white" surfaces (Carl 1963).

Immature/Other — all remaining animals. "Adult females" and "immature males" are not readily distinguishable from each other on the basis of dorsal fin shape. They are classified as one group until adequate evidence is obtained to advance them to one of the more precise categories for adult animals. This category currently includes immature animals of both sexes and females which are either sexually mature but not yet seen with a calf or are senescent. If some males in this Alaska population become sexually mature before they attain the dimorphic dorsal fin, this category also includes some adult males.

Results and Discussion

From 1984 through 1987, there were 317 separate days on which there were encounters with pods of Killer Whales in PWS resulting in photo-identification (Table 1). By the end of 1984, 188 Killer Whales photographed in the Sound had been identified and assigned to pods. Work in 1985, 1986 and 1987 increased this number to 232, in 17 pods (Table 2). This increase in numbers represents our increased resolution of the population and should not be taken as evidence that the population was increasing. For example, two pods (AT 60 and AT 70, a total of 10 whales) were first identified in 1987, and some adult members of other known pods were not identified until after the year in which their pods were first catalogued (Table 3). No new "resident"-type pods have been identified since 1984. Some births and deaths have occurred in several pods (Table 3 — see below for discussion).

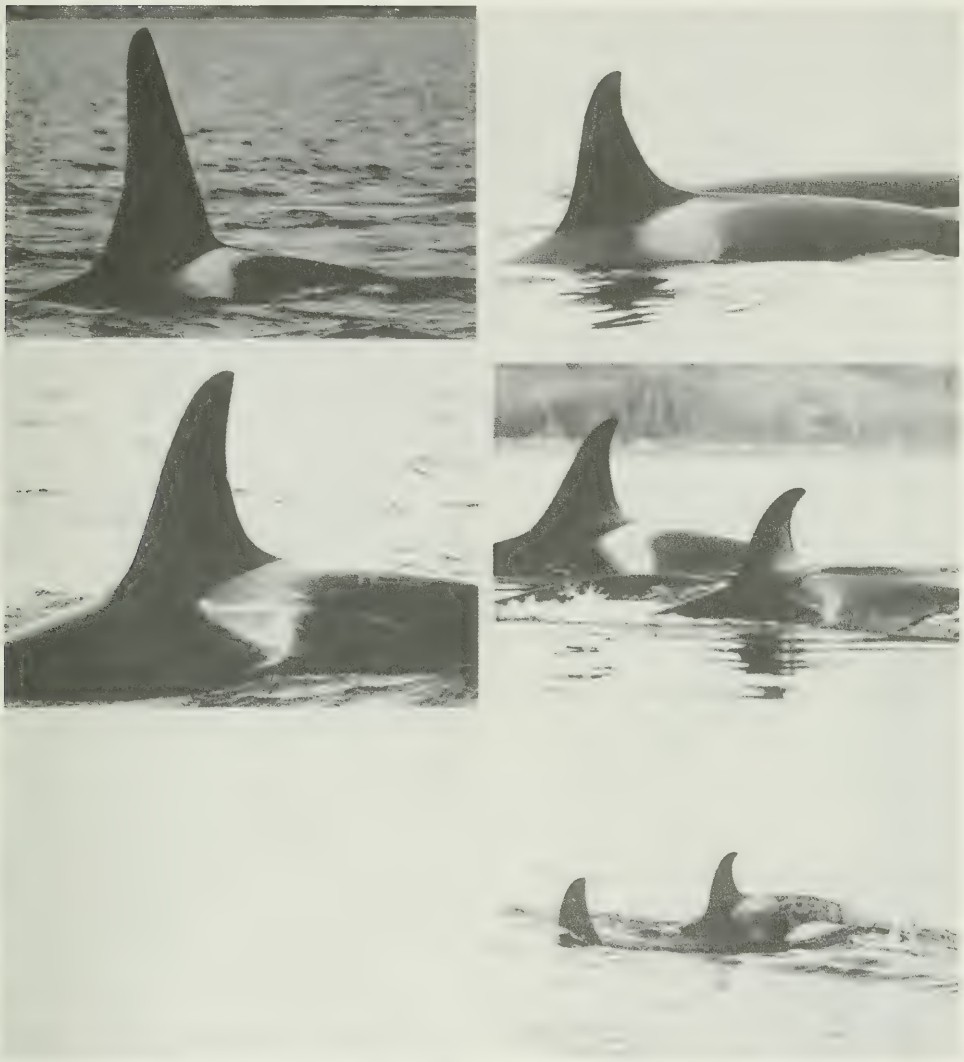

FIGURE 2. Representatives of the various age/sex classes of Killer Whales: A — an adult male, AB1; B — an adult female, AB10; C — a female/subadult male, AN7; D — a juvenile, AN22, in foreground; and E — a calf, AE13. (C. O. Matkin, 4 June 1984 (A), 2 September 1984 (B), 19 September 1984 (C), 2 September 1984 (D) and 4 August 1985 (E)).

An annual summary of encounters with each individual is shown in Table 3. Animals marked with an "X" have not been recognized in the series of most recent encounters with their pod, despite ample photographic coverage. Following the logic of Bigg (1982), these animals are presumed dead.

The known composition and history of identifications of individuals in each pod are summarized in Tables 2 and 3, respectively; some additional details of a few pods are discussed briefly below:

RESIDENTS

AB Pod: This is one of the largest pods known in Prince William Sound. It has been one of the most easily approached groups, and is frequently observed from tour vessels. Members were identified from photographs taken in 1976, 1979, 1980, and 1983. By the end of our 1984 season, during which the pod was encountered on 34 days, 35 members were known (Leatherwood et al. 1984).

In 1985, Killer Whales were reported to be interfering in Prince William Sound with longline

TABLE 1. Numbers of days on which pods of Killer Whales were encountered in Prince William Sound, 1984 through 1987 (AT40 pod is not included as it was only seen in 1983 — see Table 3).

	AB	AC	AD	AE	AF	AI	AJ	AK	AN	AS	AU	AT 1	AT 30	AT 50	AT 60	AT 70	
1984	34	1	9	11	4	24	10	6	15	3	0	12	0	0	0	0	Leatherwood et al. (1984)
1985	12	1	5	13	4	15	0	6	8	1	4	15	1	0	0	0	Matkin et al. (1985); Hall and Cornell (1986; 1987)
1986	15	0	11	10	4	8	8	3	10	1	0	10	0	1	0	0	Matkin et al. (1986, 1987)
1987	12	0	0	0	0	8	1	3	11	0	0	3	0	0	1	1	(Matkin 1988)
	73	2	25	34	12	55	19	18	44	5	4	40	1	1	1	1	TOTAL
Total = encounters																	

fisheries for Sablefish, or "Blackcod", *Anoplopoma fimbrica*. After investigating these and subsequent reports, Matkin (1986) confirmed that Killer Whales were affecting landings and damaging fishing gear in this fishery. He concluded that members of AB pod were involved exclusively, and reported that some fishermen were retaliating by shooting the animals. Corroboration for the latter is given by Hall and Cornell (1986), who published photographs of 8 members of AB pod (AB 1, 7, 12, 16, 21, 30, 31, and 34) which during encounters in 1984 lacked bullet wounds in evidence during encounters with them in 1985. Further research into the interactions of Killer Whales and the longline fisheries is described in Matkin et al. (1986, 1987, 1988).

Members of AB pod were "missing" (not seen and recognized) in the series of encounters with the pod in the 1985 (2 individuals), 1986 (4), and 1987 (1) field seasons; all 7 are presumed dead. The six animals missing by the end of 1986 included 3 of 8 reported as having been wounded by gunshot in 1984/85 (Matkin 1986; Hall and Cornell 1986). Another of the animals wounded by gunshot, possibly in 1985, is included in the 1987 mortalities but was already missing by the latter part of the 1986 season.

AF Pod: After the 1984 field season, the pod was believed to contain 21 members. Additional calves were identified in 1985 (1) and 1986 (1). However, only 11 members, including these two calves, were accounted for after 1984. This may mean that there was an error in the original pod designation or that the pod has temporarily split into two sub-pods, as sometimes occurs in the population in British Columbia (Bigg et al. 1987). Members of AF pod are known to have travelled between PWS and SEA at least once each year in 1984, 1985, and 1986.

AI Pod: Members of this pod are often in the company of AB pod.

AJ Pod: Only 22 and 10 of the pod's 25 members were photo-identified in 1986 and in 1987, respectively. However, as AJ pod was encountered in mixed pods in all but one instance, it is possible that the missing animals were simply overlooked; therefore, they are not yet listed as mortalities.

AN Pod: This is currently the largest pod in Prince William Sound (37 animals).

AS Pod: This group remains poorly known, as it has been encountered infrequently and always in multi-pod aggregations. It contains at least 9 members.

TRANSIENTS

AT 1 Pod: The pod was known to contain 22 individuals by 1984, although 2 animals (AT21 and AT22) were not photographed adequately by 1984 to permit them to be catalogued. Members of this pod have been seen mainly in small groups rather than in a large cohesive pod. Only a few members were photographed in 1987.

TABLE 2. Size and composition of pods of Killer Whales photo-identified in Prince William Sound, Alaska, 1976 through 1987. [(R) = Resident; (T) = Transient; + = calf born 1986 or 1987 — for year of birth see Table 3; *Missing and presumed dead].

Pod	No. of Animals Photoidentified	Adult Males	Adult Females	Immature/others[1]	Calves (+)
AB (R)	39(7*)	1*,2,3,4,5,29	6,17,23,32, 14,10,7*	8,11,13,16,18,19,20,21 22,24,25,26,27,30,31, 33,35,9*,34*,15*,12*,28*	36,37,38,39
AC (T)	4	3,4	—	1,2	—
AD (R)	19	1,2,3,13	5,11	4,6,7,8,9,10,12,14,15, 16,17,18,19	—
AE (R)	14(2*)	1,9	5,11	2,3,6,7,10,12,13,14, 4*,8*	—
AF (R)	24	1,2,3,18	6,8	4,5,7,9,10,11,12,13,14, 15,16,17,19,20,21,22,23	24
AI (R)	6	1,2	3	4,5,6	—
AJ (R)	25	1,2,11,16,17	8,14	3,4,5,6,7,9,10,12,13,15, 18,19,20,21,22,23,24,25	—
AK (R)	9(1*)	2,4	6	1,3,7,8,5*	9
AN (R)	38(1*)	1,2,3,4,21	9,13,23	5,7,8,10,11,12,14,15,16,17, 18,19,20,22,24,25,26,27, 28,29,30,31,32,33,34,35,6*	36,37,38
AS (R)	9	1,10	—	2,3,4,5,6,9,11	—
AT1 (T)	22	1,5,11,13,14,15, 16,17,21	9	2,3,4,6,7,8,10,12,18, 19,20,22	—
AT30 (T)	2	30,31	—	—	—
AT40 (T)	2	40,41	—	—	—
AT50 (T)	6	50,55	—	51,52,53,54	—
AT60 (T)	5	60	—	61,62,63,64	—
AT70 (T)	5	70	—	71,72,73,74	—
AU (T)	3	1	1	1	—
Total	232	52 (22.4%)	22 (9.48%)	149 (64.22%)	9 (3.88%)
Missing	-11*	-1*	-1*	-9*	-0*
Total Live	221	51 (23.1%)	21 (9.50%)	140 (63.35%)	9 (4.07%)

[1]May include some adult females.
†Includes animals of both sexes age 2 yrs. or older.

The information in this paper can best be regarded as a report of progress. Even so, the data on Killer Whales of southern Alaska presented here, considered in context of other data from the region (Leatherwood et al. 1984; Matkin 1986; Hall and Cornell 1986; von Ziegesar et al. 1986; Matkin et al. 1985, 1986, 1987) support some tentative conclusions.

Killer Whales in Prince William Sound, like those in British Columbia (Bigg 1982) and Puget Sound (Balcomb et al. 1980), tend to occur in groups that exhibit longterm stability. Also, the same pods have been repeatedly photo-identified in PWS year after year, suggesting that they have a preference for specific geographic areas. These pods appear to have seasonal home ranges that overlap with the ranges of other pods. AB and AI pods, in particular, are more likely than others to be encountered in PWS and perhaps center their ranges in the Sound. One "transient" pod, AT1, was seen in PWS more frequently than 6 of the 9 "resident" pods, suggesting that it also centers its range in the PWS region. All other transient pods were seen very infrequently.

At the end of the 1987 season, the nine pods of "resident"-type animals contained an average of 19.1 individuals (SD = 11.14), the eight pods of "transient"-type animals an average of 6.13

TABLE 3. Individual Killer Whales photo-identified in Prince William Sound, 1976-1987.

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
AB	1976							+																							+	+								
	1979	+	+															+							+														
	1980	+	+	+	+																																			
	1983	+	+		+	?	+				+									+																			
	1984	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				
	1985	±	+	±	±	+	+	±	+	X	+	+	±	+	+	X	±	±	±	+	+	±	+	+	+	+	+	+	±	+	±	±	+	+	±	+				
	1986	X	+	+	±	+	+	X	+	X	+	+	*	+	+	X	+	+	+	+	+	+	+	+	+	±	+	+	+	+	+	+	+	+	X	+	⊕	⊕			
	1987	X	+	+	+	+	+	X	+	X	+	+	X	+	+	X	+	+	+	+	+	+	+	+	+	+	+	+	X	+	+	+	+	+	X	+	+	+	⊕	⊕

Pod	Year	1	2	3	4
AC	1978		?		
	1983	+	+	?	?
	1984	+	+	+	+
	1985	+	+		+

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
AD	1977			+																
	1983													+	+					
	1984	+	+	+	+	+	+	+	+	+	+			+	+	+	+			
	1985	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	⊕	+
	1986	+	+	+	+	+	+	+			+	+	+	+	+	+	+		+	+

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
AE	1977									+					
	1982	+								+	?				
	1984	+	+	+	+	+	+	+	+	+	+	+	+		
	1985	+	+	+	+	+	+	+	X	+	+	+	+	⊕	+
	1986	+	+	+	X	+	+	+	X	+	+	+	+	+	+

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AF	1976	?																							
	1983	+	+	?	+							+				+									
	1984	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	+	o	+	+	
	1985	+	+				+	+	+		+				+		+			+		⊕	+		
	1986	+	+				+	+	+		+						+			+		+	+		⊕

Pod	Year	1	2	3	4	5	6
AI	1982					+	
	1983	+	+	?		?	?
	1984	+	+	+	+	+	+
	1985	+	+	+	+	+	+
	1986	+	+	+	+	+	+
	1987	+	+	+	+	+	+

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
AJ	1976											+														
	1977											+														
	1984	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	1986	+	+	+	+	+	?		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
	1987		+					+	+		+	+	+	+	+	+										

Pod	Year	1	2	3	4	5	6	7	8	9
AK	1983	+	+	+	+		+	?		
	1984	+	+	+	+	+	+	+		
	1985	+	+	+	+	+	+	+	⊕	
	1986	+	+	+	+		+	+	+	⊕
	1987	+	+	+	+	X		+	+	+

Pod	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
AN	1977			+																																			
	1980				+																																		
	1983		+	+		?	?	+	+		+																		+	+	+							
	1984	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
	1985	+		+	+	+	+	+	+	+	+				+		+	+	+	+	+	+	+	?		+		+			+	+		?	+				
	1986	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	⊕		
	1987	+	+	+	+	+	X	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	⊕	⊕	

Pod	Year	1	2	3	4	5	6	7	8	9	10	11
AS	1984	+	+	+	+	+	+	o	o	+	+	+
	1985		+	+	?		+	o	o	+	+	+
	1986				+	+		o	o		+	?

Continued

TABLE 3. *Concluded*

Pod	Year	Individual Number																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
AT1	1978							+								+	+						
	1980									+				+									
	1982					+																	
	1983	+	+		+								+		+					+	+		
	1984	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
	1985	+	+	+	+	+		+		+	+	+	+	+	?	+		+	+	+	+	+	
	1986	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
	1987					+				+	+	+			+	+			+				

		30	31
AT30	1985	+	+

		40	41
AT40	1983	+	+

		50	51	52	53	54	55
AT50	1986	+	+	+	+	+	+

		1	2	3	4	5
AT60	1987	+	+	+	+	+

		1	2	3	4	5
AT70	1987	+	+	+	+	+

		1	2	3
AU	1985	+	+	+

Note: (+) = positive identification, (?) = probable identification, (o) = number not assigned, (⊕) = calf, (X) = missing and presumed dead, (±) = possibly wounded (±) = known wounded and (*) = first missing in 1986, confirmed dead the following year.

individuals (SD = 6.58). There is a significant difference between the two (T-Test, $\alpha = 0.01$).

The gross age/sex composition of the PWS population(s), as ascertained through 1987, does not appear appreciably different from the age/sex compositions of other Killer Whale populations being studied by photo-identification (Table 4). However, the proportions of the PWS population assigned to each age/sex category to date should be considered preliminary and should not be used for any demographic calculations. Further, one must be cautious in comparing reported age/sex compositions in different areas, for the reasons discussed below.

The criteria for various age/sex classes have not been defined uniformly. The various terms (calf, juvenile, immature, subadult, cow and bull) have been applied slightly differently by different investigators and often used without clear delineations among the classes. For example, it is not possible to separate "calves" from "juveniles" when the investigators have lumped them or to determine when adult females which are senescent or without calves during the periods of observation have been erroneously included in the more comprehensive categories intended for animals not sexually mature. In the PWS study, for example, some animals previously considered "females or subadult males" (Ellis et al. 1987) have been reclassified herein as "adult females" after being seen repeatedly in 1987 with a calf or yearling.

Published figures presumably refer only to a single year (usually the most recent) in a multi-year study; they do not show how the composition (or apparent composition), which may be biased in early years of studies, has changed with the length of study. Such changes may be considerable (for example, see Table 4, Iceland (1) and (2) and PWS (1), (2), and (3)). Further, some animals have not been photographed recently and their classifications are based on the last encounter with them. Since they were last identified, some of these may have advanced from the comprehensive classes ("juveniles/calves" and "females/subadult males") to which they were assigned when last photo-identified.

Finally, ability to resolve composition of a population accurately depends on how well one can define the population(s) to which the figures refer (i.e., is the population under study open or closed).

The animals easiest to classify are adult males, newborn calves and cows with calves (= adult females), in that order. For both adult classes used in this study, sexual maturity may have occurred before the required indicators are observed; therefore, both classifications are conservative and as such are likely to under-represent the number of sexually mature animals in the population.

Recent work has shown that there may be substantial problems in developing population models for long-lived, birth pulse populations (e.g.,

TABLE 4. Gross average age/sex composition of Killer Whales derived from photo-identification studies in various regions.

Area	Age/Sex Class				
	Adult Males (AM)	Females (F)	Juveniles (J)	Calves (C)	Source of data
British Columbia 1973-1981	23.0%	34.1%	38.5%	4.4%	Bigg (1982)
	AM	Females Subadult Males (F/SA)	J/C		
Iceland (1), 1981-1985	18.4%	71.1%	10.5%		Lyrholm et al. (1987)
Iceland (2), 1981-1986	29.0%	58.0%	13.0%		Sigurjonnsson et al. (1988)
Southeast Alaska, 1984	18.6%	48.6%	32.8%		Leatherwood et al. (1984)
Prince William Sound (1), 1976-1984	19.2%	54.5%	26.3%		Leatherwood et al. (1984)
	Known Males	Known Cows	F/SA	J/C	
PWS(2) 1976-1987	30.4%	12.5%	26.2%	30.9%	Ellis et al. (1987)
	AM	AF	Immatures/ Others	C	
PWS(3) 1976-1987	22.4%	9.5%	64.2%	3.9%	this paper

many cetaceans), based on life table projections or overly simplified projection models (Taylor, Carley, and Bunnell 1987). For calculation of some vital parameters, Killer Whales may be treated as a special case. Bigg (1982) and Bigg et al. (1986) found no emigration or immigration within the "resident-type" pods in British Columbia; under such circumstances each pod can be viewed as a separate, closed population unit. Assuming the same situation exists in PWS, one can use the data presented in this paper to compute provisional mortality rates for some of the better documented pods.

From 1984 to 1986, the combined mortality rate for all ages and both sexes was 1.9 percent in AN, AE, and AI pods, similar to the rate of 1.7 percent that can be derived from data collected in B.C. and Washington (Bigg 1982). By contrast, it was 7.4 percent in AB pod. A total of 39 members was photoidentified in AB pod from 1984 through 1987. Six of the 39 died in 1985-1986, 1 in 1987. The relatively higher mortality rate in 1985-1986 coincided with the appearance on some whales in AB pod of bullet wounds apparently inflicted during interactions with the blackcod fishery. No new wounds were observed in 1987, by which time the mortality rate had declined to 2.9 percent (Matkin 1988). AB pod is the only group of whales confirmed to have interacted with the sablefish fishery in Prince William Sound, 1985-1987.

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Critical Fall Staging Sites for Shorebirds Migrating Through the St. Lawrence System, Quebec

CHARLES MAISONNEUVE,[1] PIERRE BROUSSEAU, and DENIS LEHOUX

Canadian Wildlife Service, 1141 rte de l'Église, Sainte-Foy, Quebec G1V 4H5
[1]Present address: 102 rue Roy, Saint-Isidore, Quebec G0S 2S0

Maisonneuve, Charles, Pierre Brousseau, and Denis Lehoux. 1990. Critical fall staging sites for shorebirds migrating through the St. Lawrence system, Quebec. Canadian Field-Naturalist 104(3): 372–378.

Surveys conducted in 1980 and 1981 and results originating from unpublished studies were used to assess the importance of the St. Lawrence River, Estuary and Gulf for fall-migrating shorebirds. At least 160 000 shorebirds representing 22 species stop over in the area. In the St. Lawrence system as a whole, the sector between Québec and Matane showed the highest concentration of birds; this sector alone accounted for nearly 70% of the total bird count. Our data indicate that Ile Rouge, the Havre aux Basques Lagoon and the Portneuf Sandbar can be considered among the most important known sites in eastern North America for the Black-bellied Plover (*Pluvialis squatarola*), Short-billed Dowitcher (*Limnodromus griseus*) and White-rumped Sandpiper (*Calidris fuscicollis*) respectively.

Des inventaires réalisés en 1980 et 1981, de même que les résultats d'études non publiées, ont servi à déterminer l'importance du fleuve, de l'estuaire et du golfe du Saint-Laurent pour les oiseaux de rivage en migration d'automne. Au moins 160 000 individus représentant 22 espèces s'arrêtent dans la région. Dans l'ensemble du système du Saint-Laurent, la zone comprise entre Québec et Matane abrite les concentrations les plus élevées; près de 70% des effectifs inventoriés y sont rassemblés. Nos résultats indiquent que l'Ile Rouge, la lagune du Havre aux Basques et le Banc de Portneuf peuvent être considérés parmi les plus importants sites dans l'est de l'Amérique du Nord pour le Pluvier argenté (*Pluvialis squatarola*), le Bécasseau roux (*Limnodromus griseus*) et le Bécasseau à croupion blanc (*Calidris fuscicollis*) respectivement.

Key Words: Shorebirds, St. Lawrence River, fall migration, staging sites, distribution.

The importance of the St. Lawrence system as a migratory staging area for waterfowl and a breeding region for various colonially-breeding birds has already been examined in numerous studies (e.g. Brown et al. 1975; DesGranges and Laporte 1983; Chapdelaine and Brousseau 1984; DesGranges et al. 1984; Lehoux et al. 1985). In contrast, little information has been published on shorebirds. However, unpublished results of the Canadian Wildlife Service, other unpublished studies and recent surveys conducted by the authors indicate large fall concentrations of shorebirds at many locations along the river, estuary and gulf of the St. Lawrence system. In order to better understand the situation, a compilation of the available data on shorebird numbers in the St. Lawrence system has been made. The information presented is essential to conservation and management strategy for these migratory bird populations, in either a regional, national or international perspective.

Study Area

The study area comprises approximately 4500 km of shoreline along the St. Lawrence system, restricted to the province of Québec (Figure 1). It extends from Cornwall, at the Ontario border, to Blanc-Sablon near the Labrador border on the north shore, and to the New Brunswick border located at the mouth of the Restigouche River on the south shore. The îles-de-la-Madeleine are included in the present study, but Anticosti island is not because it was not covered during the shorebird surveys.

The area was divided into five separate regions on the basis of tidal influence and water salinity (for details, see Environment Canada 1985). Details on substrate types are derived from Dryade (1980, unpublished report). The freshwater zone, extending from Cornwall to Cap Tourmente near Québec, is subdivided into a lentic sector (Region 1), characterized by the absence of tides and a weak current, and a lotic sector (Region 2) subject to tidal movement. Region 1, extending to lac Saint-Pierre and covering approximately 1300 km of shoreline, includes 33 110 ha of shallow water wetlands of which 70% are colonized by submergent vegetation and 30% by emergent aquatic vegetation. Mud and rocky areas are virtually absent, and sand habitats account for only 100 ha. Region 2 comprises 4625 ha of wetlands dominated by *Scirpus* marshes, which cover 81% of the wetland area. These marshes are scattered along the 300 km of shoreline (north and south shores combined) which are predominantly occupied (75%) by extensive rocky sectors (1000 ha) uncovered at low tide and scattered with glacial boulders and a mosaic of muddy (1300 ha) and

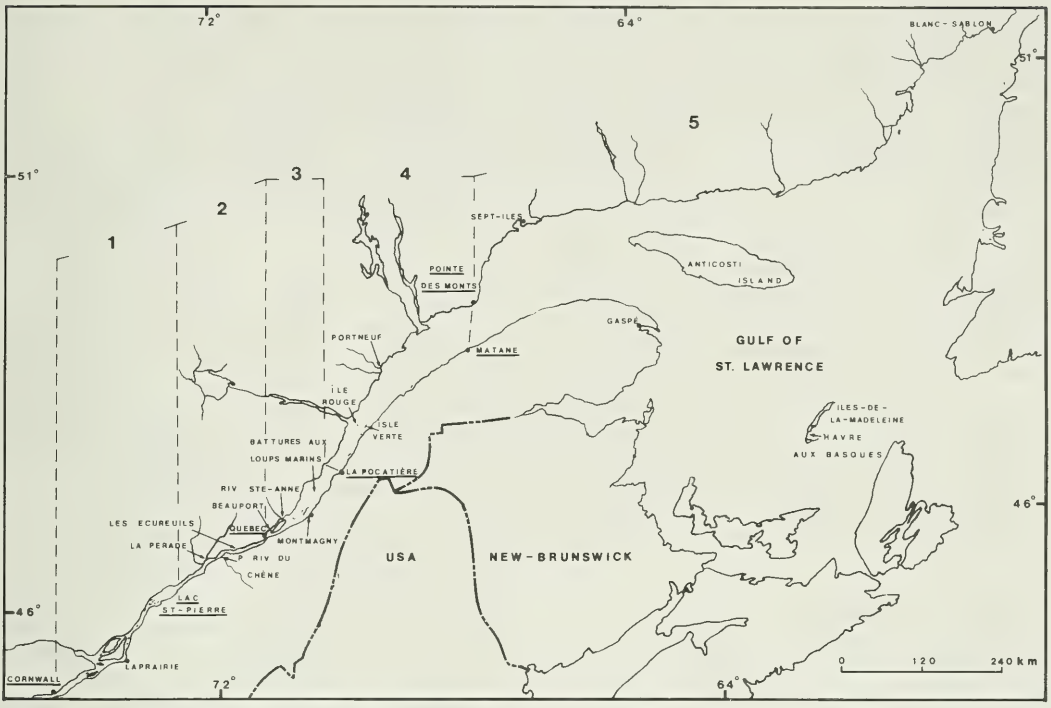

FIGURE 1. The study area showing the limits of the five regions surveyed and the major shorebird staging sites identified.

sandy (2000 ha) beaches. The following brackish water zone (Region 3), where fresh and salt water mix and tides are highest (3.5 to 5.5 meters in the fall), covers approximately 400 km of shoreline extending to Baie Saint-Paul on the north shore and to La Pocatière on the south shore. This is the region where sedimentation is most strongly in evidence, often reaching levels of 2.7 million tons dry weight per year (Sérodes 1980). The uneven deposition of fine sediments determines the distribution and size of bare areas and those with vegetative cover. In this respect, Region 3 is characterized by 2365 ha of *Scirpus* marshes, representing 34% of this type of wetland present in Québec. It also contains nearly 8000 ha of mud flats, representing 35% of that habitat type in the entire study area, along with 1500 ha of rocky areas and about 500 ha of sandy substrate. The saltwater zone succeeds and is divided into two regions: the estuary (Region 4), extending to Pointe des Monts on the north shore and to Matane on the south shore, and the gulf (Region 5), which comprises the North Shore, the Gaspé Peninsula and the îles-de-la-Madeleine. In these regions, *Scirpus* marshes are replaced by *Spartina* and salt marshes, which respectively cover 2703 ha and 1708 ha in Region 4, and 366 ha and 3255 ha in Region 5. The largest mud and sand flats in the St. Lawrence system are found along the nearly 1000 km of shoreline in Region 4 (12 000 ha and 10 000 ha respectively). These represent more than 50% of the whole study area. Region 4 also includes 500 ha of rocky flats located primarily on the north shore. The 1500 km of shoreline in Region 5 are dominated by some 10 000 ha of sandy deposits through which are scattered rocky flats and marshes.

Methods

P.B. supervised the ground surveys conducted in the freshwater zone (Regions 1 and 2) in 1980 (Brousseau 1981, unpublished report) and C.M. supervised those covering the brackish zone and the estuary (Regions 3 and 4) in 1981 (Maisonneuve 1982, unpublished report). For the gulf sector (Region 5), unpublished results originating from surveys conducted in 1977 by the Canadian Wildlife Service and from Mousseau et al. (1976, unpublished report) were used.

The 1980 and 1981 ground surveys were conducted to allow visits to 252 sites, all in a 4-week period from late July to late August coinciding with the abundance peaks of the Semipalmated Sandpiper, which is the species found in greatest numbers in eastern North America during the fall migration (Morrison and Harrington 1979). Because of the vastness of the

study area, we restricted our sampling of survey sites. Selected locations were: (1) major sites (250 birds or more) identified on the basis of information gathered by amateur ornithologists; (2) river estuaries easily accessible by land; and (3) large bays and mudflats (15 to 100% of surface area).

Two teams of two observers shared the work of making single visits to each of the 252 sites. Telescopes (25X) were used for all birds counts except in the case of some islands where surveys were conducted with binoculars (7 × 35) from a boat running 30 to 50 m offshore. The surveys were made over the entire daytime period (0800 h to 1900 h). In the section influenced by the tides (downstream of lac Saint-Pierre), counts were carried out where possible at low or middle tide. At each site, the total number of birds was recorded for each species; under poor observation conditions, congeneric species were combined.

Results

Region 1: Cornwall — Lac Saint-Pierre

This region supports a small shorebird population of about 2000 to 4000 sandpipers and yellowlegs (Table 1). It is doubtless that the absence of muddy and sandy habitats, as well as the intense human activity along the shoreline, are major limiting factors. However, the diversity of species (14) is high. The Semipalmated Sandpiper and yellowlegs (Lesser and Greater combined) dominated the regional counts, with 39% and 28%, respectively, of the total census. The Semipalmated Sandpiper and sandpiper species combined accounted for 61% of the total number of birds counted in the region. Only two of the 78 locations visited had major bird concentrations: Laprairie and Ile du Moine, which comprised 53% and 10%, respectively, of all birds counted in the region.

Region 2: Lac Saint-Pierre — Québec

The dominant shorebird species in this region in the fall are the Semipalmated Sandpiper and, to a lesser extent, the yellowlegs, of which the Lesser Yellowlegs comprises 97% of the birds identified to species. These species made up 82% and 3% respectively of the 7300 birds counted and occurred in 72% and 50% of the 40 sites surveyed. Overall, only three sites were judged to be important (based on numbers of birds present): Petite Rivière du Chêne, La Pérade and les Ecureuils, each of which support 800-2000 birds.

Region 3: Québec — La Pocatière

Nearly 70 000 birds, comprising 20 species, were counted in the region. The Semipalmated Sandpiper was most numerous and accounted for nearly 73% of all sightings (Table 1). Unidentified sandpipers represented 23% of the total, followed by Semipalmated (1.5%) and Black-bellied (0.9%) Plovers.

Of the 51 sites visited, ten had more than 1000 birds, and four supported a population greater than 5000 birds: Montmagny (15 848), Battures aux Loups Marins (13 876), Beauport (9617) and Ste-Anne River (5000). These sites are all located near Québec and contain extensive mud flats and bulrush marshes.

Region 4: La Pocatière — Matane

A total of 42 000 shorebirds comprising 17 species were recorded in this region. The Semipalmated Sandpiper was the most abundant species, accounting for 35% of the total for the region, and was found at 61% of the 49 sites where shorebirds were observed. Moreover, if the number of unidentified sandpipers is added to the number of Semipalmated Sandpipers, the total accounts for 56% of all birds recorded and present at 91% of the shorebird sites identified. Black-bellied Plovers were also abundant, comprising 34% of the total count and occurring in 81% of the sites. The Ruddy Turnstone, the Semipalmated Plover, and the Lesser and Greater Yellowlegs accounted for 5%, 2% and 2% of the total count, respectively.

The most important sites of the 49 surveyed in the region were Ile Rouge and the Portneuf Sandbar, which comprised 32% and 23%, respectively, of the birds counted. Ile Rouge appeared to be used as a resting area by the birds whose feeding grounds on the north shore (Pointe-aux-Alouettes in particular) and the south shore (Ile Verte vicinity) were submerged at high tide.

Region 5: Gulf of St. Lawrence

The shores of the Gulf of St. Lawrence located within the Québec Province boundaries include some of the best shorebird sites in the St. Lawrence system with at least 40 000 shorebirds stopping over during the fall migration. A total of 17 species was identified, with the Semipalmated Sandpiper and the Short-billed Dowitcher being the most abundant and comprising 36% and 24%, respectively, of all birds encountered. Five species were widely distributed in the region — Semipalmated Sandpiper, Semipalmated Plover, Black-bellied Plover, Lesser Yellowlegs and Ruddy Turnstone and were recorded at over 60% of the 60 observation sites. In contrast, the Lesser Golden Plover and Pectoral Sandpiper were only rarely seen, occurring at less than 8% of the sites examined.

Among the sites examined in this region, the Havre aux Basques Lagoon, on the îles-de-la-Madeleine, stands out as an important staging area for shorebirds. Counts made in these islands represented 80% of the total count for the Gulf

TABLE 1. Shorebird distribution and abundance in the St. Lawrence system.

	1 Cornwall/ Lac Saint-Pierre	2 Lac Saint-Pierre/ Québec	3 Québec/ La Pocatière	4 La Pocatière/ Matane	5 Gulf of St. Lawrence	Total	% by species
Black-bellied Plover (*Pluvialis squatarola*)			657	14012	1506	16175	10.0
Lesser Golden Plover (*Pluvialis dominica*)			7		53	60	
Semipalmated Plover (*Charadrius semipalmatus*)	12	93	1040	1010	975	3070	1.9
Killdeer (*Charadrius vociferus*)	68	165	239	67	97	636	0.4
Plovers (*Pluvialis* spp.)				10		10	
Spotted Sandpiper (*Actitis macularia*)	265	76	98	56	75	570	0.4
Solitary Sandpiper (*Tringa solitaria*)	3	1	2			6	
Greater Yellowlegs (*Tringa melanoleuca*)	13	6	59	10	1104	1192	0.7
Lesser Yellowlegs (*Tinga flavipes*)	601	200	272	7	1963	3043	1.9
Yellowlegs (*Tringa* spp.)	364	23	222	914	34	1557	1.0
Pectoral Sandpiper (*Calidris melanotos*)	5	11		7	3	26	
Baird's Sandpiper (*Calidris bairdii*)	4		15			19	
Least Sandpiper (*Calidris minutilla*)	14	10	52	177	1955	2208	1.4
Dunlin (*Calidris alpina*)	2			5		7	
Semipalmated Sandpiper (*Calidris pusilla*)	1346	6378	50798	14713	12621	85856	53.1
Sanderling (*Calidris alba*)	3		42	63	1137	1245	0.8
Red Knot (*Calidris canutus*)			16	23	1877	1916	1.2
White-rumped Sandpiper (*Calidris fuscicollis*)			127	9	1562	1698	1.1
Short-billed Dowitcher (*Limnodromus griseus*)			21	27	8360	8408	5.2
Sandpipers (*Calidris* spp.)	783	307	15998	8745	3357	29190	18.1
Whimbrel (*Numenius phaeopus*)			1	43	391	435	0.3
Hudsonian Godwit (*Limosa haemastica*)			10	15	632	657	0.4
Ruddy Turnstone (*Arenaria interpes*)	1		316	1989	1254	3560	2.2
Wilson's Phalarope (*Phalaropus tricolor*)	2		1			3	
Red-neck Phalarope (*Phalaropus lobatus*)			1			1	
Phalaropes (*Phalaropus* spp.)	13		2			15	
Total	3499	7270	69996	41902	38896	161563	100.0
%	2.2	4.5	43.3	25.9	24.1	100	
Number of sites	78[1]	40[1]	50[1]	84[1]	60[2]	312	

[1]Covered in 1980-1981
[2]Not covered in 1980-1981

TABLE 2. Maximum shorebird numbers observed at various sites in eastern Canada and number of visits made to obtain these figures[1].

Site	Maximum number	Year	Number of visits
Mary's Point, N.B.	352 991	1977	48
John Lusby Marsh, N.S.	101 174	1977	?
Grande Anse, N.B.	75 011	1976	64
Dorchester Cape, N.B.	72 950	1976	?
Evangeline Beach, N.S.	42 171	1976	?
Minudie, N.S.	30 000	1978	2
Grand Pré, N.S.	25 156	1975	10
Havre aux Basques, P.Q.	21 712	1973	7
Saints Rest Marsh, N.B.	21 575	1976	2
Daniel's Flats, N.B.	20 000	1978	1
Montmagny, P.Q.	15 848	1980	1
Manawangonish, N.B.	15 414	1974	7
Noel Bay, N.S.	15 099	1976	5
Cape Sable, N.S.	14 389	1980	7
Battures aux Loups Marins, P.Q.	13 876	1980	1
Maces Bay, N.B.	13 797	1976	9
Oak Island East, N.S.	13 645	1979	?
Ile Rouge, P.Q.	13 401	1981	1
Gannet Rock, N.B.	11 000	1977	1
Black Rock, N.S.	10 087	1982	7
Beauport, P.Q.	9 617	1980	1
Portneuf, P.Q.	9 517	1981	1
Castalia Marsh, N.B.	9 006	1978	11
Quaco Bay, N.B.	8 740	1974	7
Cook's Beach, N.S.	8 620	1983	6

[1]Figures from the Maritimes taken from Maritimes Shorebird Survey (1974-1984, Canadian Wildlife Service unpublished reports) and Hicklin (1987)

region, of which 55% came from the Lagoon alone. Most of the Hudsonian Godwits recorded occurred in the Gulf region, with 632 of the 657 birds reported from the îles-de-la-Madeleine.

Discussion

At least 160 000 shorebirds comprising 22 species visit part of the St. Lawrence system each fall. The region between Québec and Matane (Regions 3 and 4) appears to be a major shorebird stopover as 69% of all shorebirds counted occurred there. In the Gulf region, only the îles-de-la-Madeleine appear to be important, although Anticosti Island was not examined. These differences may be explained by the relative availability of suitable feeding habitats for shorebirds. Upstream of Québec, the surface area of regularly exposed habitats is relatively small and sedimentation is not extensive, while downstream of Matane the shoreline becomes mainly rocky. The presence of large, shallow lagoons where tidal action is limited enhances the appeal of the îles-de-la-Madeleine to shorebirds.

Slightly over half of the shorebirds surveyed along the St. Lawrence were concentrated at only six sites. The most important one was the Havre aux Basques Lagoon, where 12% of the total numbers were sighted. Montmagny, Battures aux Loups Marins, Ile Rouge, Beauport and the Portneuf Sandbar followed, accounting respectively for 10, 9, 8, 6, and 6% of the total. In Table 2 we compare the figures obtained for these sites with the peak numbers obtained by Hicklin (1987) and those recorded during the Maritimes Shorebird Survey between 1974 and 1984 (Morrison 1976a, 1976b, 1978a, 1978b, 1983; Morrison and Campbell 1983a, 1983b, 1984, 1985, 1986; Morrison and Gratto 1979: for convenience, these unpublished reports will be cited as "Maritimes Shorebird Survey 1974-1984" in the following text). While our sites were visited only once, they ranked favourably among the best 25 sites in eastern Canada. If they had been surveyed repeatedly, as were the Maritimes sites, and the observed maxima summed up for each species, a number of our sites might likely have ranked higher.

Not only do the sites identified along the St. Lawrence compare favorably with others in eastern Canada in terms of total numbers of staging shorebirds, but some of these may be of international importance for the survival of

particular species. In a time when interest in shorebird conservation and protection is growing (Morrison 1983, 1984; Senner and Howe 1984; Myers et al 1987a, 1987b), the International Association of Fish and Wildlife Agencies and other international conservation organizations are working with various governments to develop a shorebird refuge system. One criterion for selecting sites to be included in the system is the presence of at least 5% of the total population of a shorebird species. Our results indicate that some sites along the St. Lawrence may, for some species, exceed this minimum criterion.

About 10 000 Black-bellied Plovers were observed at high tide on Ile Rouge, and this seems to represent a considerable proportion of the population migrating through eastern North America. According to the Maritime Shorebird Survey (1974-1984), the maximum peak number of Black-bellied Plovers counted in the Maritime Provinces as a whole was about 4000, and Hicklin (1987) estimates that up to 10 000 birds of this species may migrate through the Bay of Fundy in fall. At the time of the 1976 International Shorebird Survey, a total count of 13 478 Black-bellied Plovers (summing the five highest counts taken at each of the 30 sites covered) was obtained for the eastern United States (Leddy and Harrington 1978, unpublished report). Furthermore, a total of 27 267 birds of this species were counted on the wintering grounds located on the coasts of South America (Morrison and Ross 1989). Therefore, the numbers of Black-bellied Plovers on Ile Rouge would represent 37% of the South American wintering population.

The Havre aux Basques Lagoon seems to be a major staging site for fall migrating Short-billed Dowitchers, since 7619 birds of this species were counted on this site. The highest total count obtained for this species in the Maritime Provinces (Maritimes Shorebird Survey 1974-1984) is about 7000 birds. The maximum number of Short-billed Dowitchers migrating through the Bay of Fundy in fall is estimated at about 10 500 (Hicklin 1987). Along the United States east coast, only Brigantine National Wildlife Refuge in New Jersey attracted higher numbers during the 1976 International Shorebird Survey as a total of 25 937 Short-billed Dowitchers was obtained by adding the five highest counts (Leddy and Harrington 1978, unpublished report). Some 49 000 dowitchers were observed on the coasts of South America during winter by Morrison and Ross (1989). Thus, the number of Short-billed Dowitchers observed in the Havre aux Basques Lagoon represents 16% of this wintering population.

Only 1698 White-rumped Sandpipers were counted over the entire study area. But the surveys from which this number was obtained were conducted in August and the fall migration peak of this species is reported to occur later than that of most other shorebird species. Because of this, the importance of the St. Lawrence system as a staging area for the White-rumped Sandpiper may have been underestimated. Hagar (1956 *in* Gaboriault 1961) reported some 6000 birds of this species from the Havre aux Basques Lagoon in September 1956, and another count of 6000 was reported in October 1981 for the Portneuf Sandbar (D. Bordage, Canadian Wildlife Service, Québec Region, personal communication). These sites, and possibly others where no late surveys were ever carried out, may thus be critical staging sites for White-rumped Sandpipers. The total count for this species in the eastern United States did not even reach 200 in 1976 (Leddy and Harrington 1978, unpublished report). In the Maritime Provinces, a maximum of barely 2000 has been reported during the Maritime Shorebird Survey (1974-1984), although no October counts were carried out during this survey. Nevertheless, based on surveys lasting until late fall, Hicklin (1987) estimates that only up to 3000 White-rumped Sandpipers migrate through the Bay of Fundy in fall. Considering that the majority of nearly 71 000 unidentified small shorebirds counted on the southern half of the Atlantic coast of South America were probably White-rumped Sandpipers (Morrison and Ross 1989), the number of birds of this species mentioned for each the Portneuf Sandbar and the Havre aux Basques Lagoon could represent 9% of the wintering South American population.

Recent declines have been noticed in the populations of some North American shorebird species (Howe et al. 1989), Black-bellied Plovers and Short-billed Dowitchers being among the most affected. Consequently, the staging sites identified along the St. Lawrence system are of critical importance for the survival of these species and possibly for other species for which a decline may presently be less evident. Serious efforts should be made in order to protect these sites and to eventually incorporate them into an international shorebird reserve network.

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Observations on Shoot Morphology, Anthesis, Flower Number, and Seed Production in the Saskatoon, *Amelanchier alnifolia* (Rosaceae)

RICHARD G. ST. PIERRE[1] and TAYLOR A. STEEVES

Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0
[1]Present address: Department of Horticulture Science, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

St. Pierre, Richard G., and Taylor A. Steeves. 1990. Observations on shoot morphology, anthesis, flower number, and seed production in the Saskatoon, *Amelanchier alnifolia* (Rosaceae). Canadian Field-Naturalist 104(3): 379–386.

This study characterizes some aspects of the reproductive biology of *Amelanchier alnifolia*, the Saskatoon, including shoot morphology as associated with inflorescence production, timing of anthesis, flower longevity, variability in flower number per inflorescence, and variability in seed number and mass. A typical ramet of the Saskatoon was found to be comprised of long shoots and short shoots, the latter producing flowers and fruits. Anthesis is a mass phenomenon occuring over a two-week period in any given area. The inflorescence is determinate, the most terminal flower always one of the first to bloom. Individual flowers lasted a mean of 3.5 ± 1.5 days. Variability in the number of flowers/inflorescence existed within long shoots, stems, clones, and years. Coefficients of variation for the number of flowers/inflorescence ranged from 6 to 65.5. The number of flowers/inflorescence ranged from 1 to 15, the mean varying from 5 to 11.3. Single fruit have the potential to produce 10 seeds, but average seed to ovule ratios never exceeded 0.27. Mean seed mass/fruit varied from 1.1 to 6.9 mg. The magnitude of variation of seed mass was 6.27. Mean mass/seed and the number of seeds/fruit were weakly correlated.

Key Words: *Amelanchier alnifolia*, Saskatoon, shoot morphology, inflorescence, anthesis, flower longevity, flower number, seed:ovule ratio, seed mass.

Amelanchier alnifolia, the Saskatoon, is a common native prairie shrub that grows in dense vegetatively propagated clumps and flowers in early spring. There have been few studies of the reproductive biology of the Saskatoon. These include studies of pollination biology and fruit development (Olson 1984; Olson and Steeves 1982), inflorescence development (Steeves and Steeves 1990), flower bud dehardening and hardening (Junttila et al. 1983; Kaurin et al. 1984), fruit damage by the apple curculio (Steeves et al. 1979), and the magnitude, timing and causes of immature fruit loss (St. Pierre 1989).

The objective of the current study was to characterize some aspects of the reproductive biology of the Saskatoon, including shoot morphology as associated with inflorescence production, timing of anthesis, flower longevity, variability in flower number per inflorescence, and variability in seed number and mass. Because the Saskatoon has been brought into cultivation as an indigenous fruit crop, such information is directly applicable to various horticultural procedures including the selection of superior genotypes, planning a program of breeding, and managing the plant as a crop.

Methods

Study Sites

The data were collected from two study sites. The primary site was located about 56 km SW of the city of Saskatoon (NE 31-31-6 W3) on the banks of the South Saskatchewan River (henceforth referred to as Gledhow). The basic habitat was a bench 10 m above river level, having a SSE exposure. This bench was dominated by massive clonal stands of the Saskatoon, interspersed with *Prunus virginiana, Shepherdia argentea*, and *Elaeagnus commutata*. This study site was chosen because of its lack of disturbance and the large number of Saskatoon clones available for study.

The second site was located about 16 km west of the city of Saskatoon and about 7 km north of the town of Grandora (henceforth referred to as Grandora). This study site was covered by large clonal stands of *Populus tremuloides* with scattered individuals of the Saskatoon.

Shoot Morphology and Inflorescence Production

The description of shoot morphology was based upon an arbitrary selection of 20 branches of varying size and complexity. A ramet was defined as a single aerial shoot which was usually branched.

Anthesis

Data associated with anthesis were collected in the years 1981 to 1985 for Gledhow. These data were supplemented by preserved material previously collected in 1978 and 1979 from Gledhow. Data from 1980 were not available because of a killing frost. Data associated with the

timing of anthesis were derived from 25-30 short shoots collected twice-weekly from early May to late July in the years 1981-1984. For these observations, anthesis was defined as petal spread, start of petal drop was defined as any petal abscission, and end of petal drop was defined as complete petal abscission. Data on the sequence of anthesis were collected in 1985 at Gledhow. Twenty-five inflorescences were sampled on 14 May when anthesis had just begun. Anthesis and petal drop were defined on the basis of ≥ 3 petals spread open, or abscised, respectively.

Number of Flowers per Inflorescence

Data associated with the number of flowers per inflorescence were collected from 1982 to 1985 at Gledhow. For the years 1982, 1983, and 1984, respectively, 166, 34, and 80 inflorescences were arbitrarily sampled from an undetermined number of clones. Small sample sizes in 1983 and 1984 were due to a loss of inflorescences from frost and insect damage. In 1985, flowers were counted in all inflorescences found on 5 long shoots, from each of 4 ramets, from each of 3 clones; 553 inflorescences were sampled in total.

Seed Production

Seed production was measured in terms of seed number and seed mass per fruit. Fully ripe undamaged fruit were difficult to find because of insect and fungal damage, or bird predation. In 1982, 35 ripe undamaged fruit were collected at Gledhow, and in 1984, 47 ripe undamaged fruit were collected from 91 short shoots harvested at Grandora. The seeds were removed, counted, dried at 105°C for 3 days and weighed. Total seed mass per fruit was measured in 1982, whereas individual seed masses were measured in 1984. Only plump seeds were included in this analysis and defined as viable seeds. Wrinkled and shrunken seeds were not counted; they were assumed non-viable.

Results

Shoot Morphology and Inflorescence Production

An individual ramet of the Saskatoon was composed of two basic types of shoot (defined in reference to a point of branching): long shoots, which had at least one expanded internode (≥ 1 cm in length); and short shoots, which had no expanded internodes. The main axis and the major branches were essentially long shoots. Long shoots could be either simple or complex. A simple long shoot was characterized by having no short shoots, and typically was comprised of current year's growth and previous years' growth (Figure 1). The alternate leaves did or did not have visible axillary buds. The terminal bud could be large and floral in character, in which case continued growth was sympodial. A complex long shoot was characterized by bearing one or more short shoots and often no current year's increment in length (Figure 2). On mature ramets, long shoots could have only 1 or 2 expanded internodes and many short shoots.

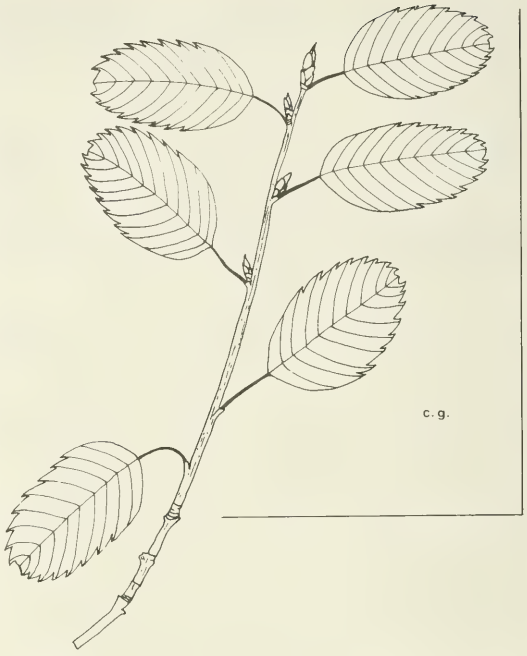

FIGURE 1. A simple long shoot of the Saskatoon; c.g. — current year's growth.

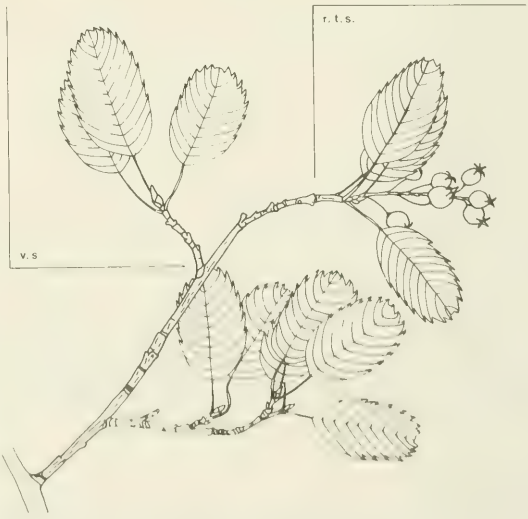

FIGURE 2. A complex long shoot of the Saskatoon, v.s.-vegetative short shoot; r.t.s.-terminal reproductive short shoot.

FIGURE 3. A typical reproductive short shoot of the Saskatoon.

Short shoots had a short woody portion bearing a large number of leaf, bud and inflorescence scars. A short shoot could be branched, thus forming a cluster of short shoots, or alternatively, an axillary bud could expand to initiate another long shoot, although this did not appear to be common as evidenced by the large number of scars. Short shoots could be either vegetative or reproductive. A typical vegetative short shoot contained a number of leaves (usually 2 or 3) and a terminal bud. This bud could be a floral bud, and in the following season, the short shoot would therefore become reproductive. A typical reproductive short shoot was composed of 1 or 2 leaves with usually 1 axillary bud (and sometimes another leaf with an axillary bud and 1 or 2 additional leaves), another leaf with a flower in its axil, and then the main axis of the inflorescence (Figure 3). Each flower arose in the axil of a bract.

Anthesis

The Saskatoon was one of the first plants to bloom at the study sites. Peak anthesis (the time at which greater than 50% of the flowers in a sample were open) was chosen as a key reference point in describing the phenology of the Saskatoon. Anthesis was a mass phenomenon in any given area; the dates of first anthesis and the completion of petal drop (Table 1) indicated that the total period for anthesis for the population studied varied from 10 to 20 days, depending upon year. The mean period of anthesis (± standard deviation) was 14.3 ± 3.4 days. Flowers in bloom were usually present from early May to late May, or from mid May to early June (Table 1).

Within individual inflorescences, the most terminal flower was always one of the first to bloom, along with the most basal flowers. Of 25 inflorescences examined, all had the terminal and basal 3 to 4 flowers open, and none of the mid-position flowers open. Once anthesis had begun, flowers lasted a mean (± standard deviation) of 3.5 ± 0.8 days (n = 20 flowers), varying from 2 to 5 days until petal drop.

Number of Flowers per Inflorescence

There was considerable variability evident in the number of flowers per inflorescence in the Saskatoon, despite the unit sampled (long shoot, ramet, clone, or year). In terms of yearly variability, the mean number of flowers per inflorescence varied from 7.4 (1985) to 11.2 (1983). The coefficients of variation (a relative measure of variability) ranged from 15.6 to 30.3, with values between 15 and 20% being the most common (Table 2). In 1985, the coefficients of variation for the number of flowers per inflorescence ranged from 6 to 65.5 within long shoots, from 15.8 to 41 within ramets, and from 23.2 to 34.7 within clones;

TABLE 1. Dates and length of anthesis for the Saskatoon at Gledhow, 1978 to 1984.

Year*	Dates of Anthesis: First Flowers	Dates of Anthesis: Peak Number of Flowers	Dates of Petal Drop: Start	Dates of Petal Drop: Finish	Length of Anthesis (Days)
1978 (167)	12 May	19 May	19 May	25 May	14
1979 (152)	—	27 May	1 June	7 June	12
1981 (261)	7 May	14 May	14 May	21 May	15
1982 (395)	12 May	17 May	21 May	26 May	15
1983 (331)	18 May	24 May	30 May	6 June	20
1984 (295)	8 May	15 May	15 May	17 May	10
Mean ± s.d.					14.3 ± 3.4

*Numbers of flowers examined each year are in brackets.

TABLE 2. Variability in the number of flowers/inflorescence for the Saskatoon at Gledhow, 1982-1985.

	1982	1983	1984	1985
Number of inflorescences sampled	166	34	80	553
Range of number of flowers/inflorescence	2-13	7-14	6-13	1-14
Mean ± s.d. flowers/inflorescence	9.0 ± 1.6	11.2 ± 1.8	9.6 ± 1.5	7.4 ± 2.2
Coefficient of variation (%)	17.8	16.1	15.6	30.3

the mean (± standard deviation) number of flowers per inflorescence ranged from 5 ± 0.5 to 11.3 ± 4, depending on which of the units was sampled.

Frequency distributions of the number of flowers per inflorescence indicated that the number of flowers per inflorescence tended to be strongly clustered around a mode of 8 and 9 for the years 1982 and 1985 respectively; the frequencies of the more extreme numbers decreased rapidly. Frequency distributions for years 1983 and 1984 were relatively flat over a range of 6 to 14 flowers per inflorescence (Figure 4).

Seed Number and Mass

A single fruit from the Saskatoon has the potential to produce 10 seeds, but this potential was rarely achieved. Of the fruit examined in 1982, 82.9%, and in 1984, 86% (n = 35 and 43 fruit, respectively) contained from 1 to 3 viable seeds. A further 11.4-14% of the fruit examined contained 4 or 5 seeds, and only 0 to 5.7% of the fruit examined in both years contained more than 5 seeds (Figure 5). The mean (± standard deviation) number of seeds per fruit was 2.7 ± 1.8 in 1982 and 2.0 ± 1.2 in 1984; seed to ovule ratios were therefore 0.27 and 0.2 respectively. Consequently, 73-80% of the

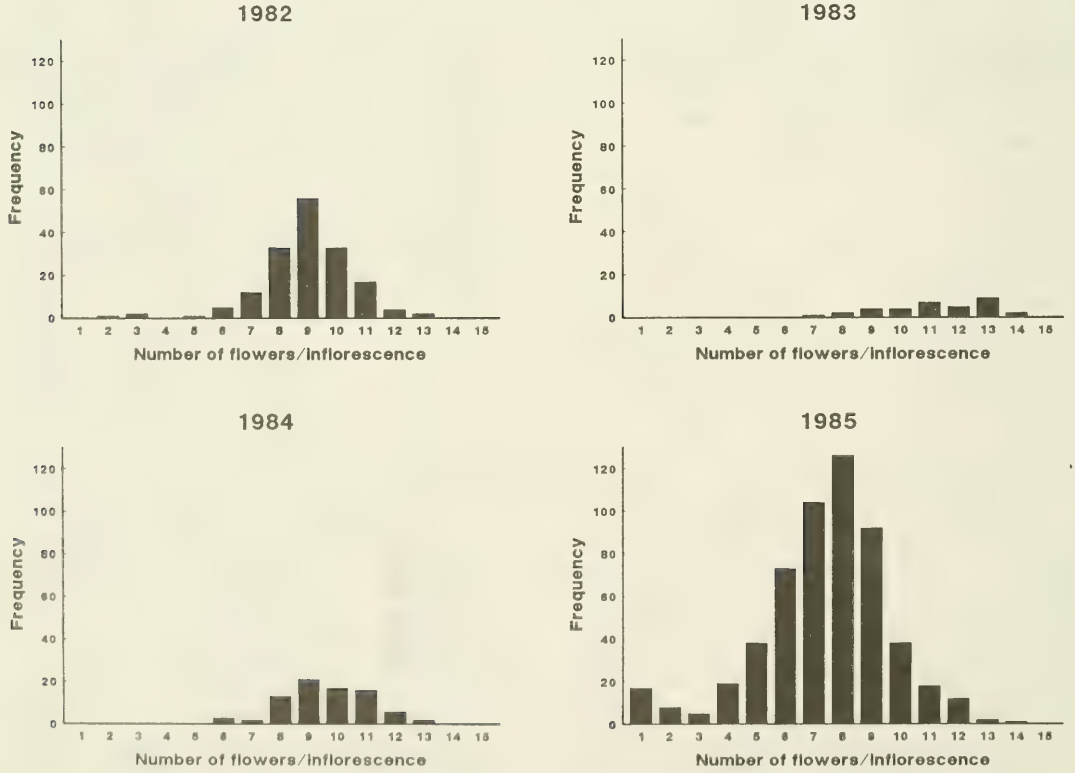

FIGURE 4. Frequency distributions of the number of flowers/inflorescence for the Saskatoon at Gledhow, 1982-1985; n = 166, 34, 80 and 553 inflorescences sampled per year, respectively.

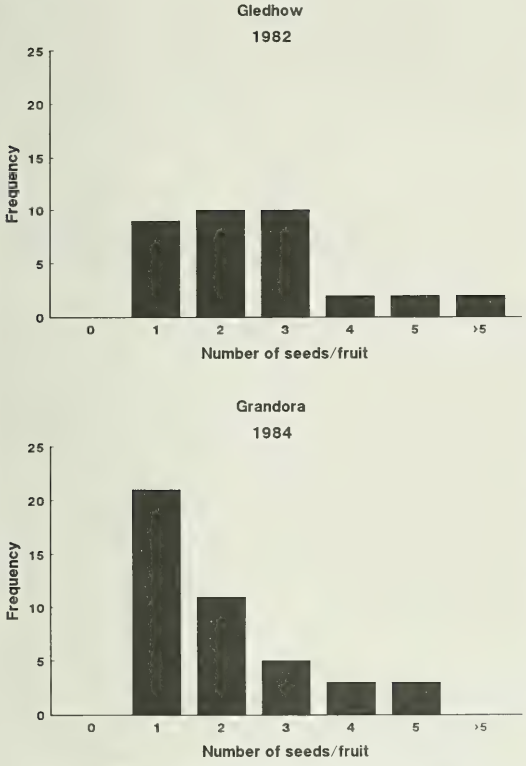

FIGURE 5. Frequency distributions of the number of seeds/fruit for the Saskatoon at Gledhow (1982) and Grandora (1984); n = 35 and 43 fruit sampled per site, respectively.

potential for seed production was never realized for reasons other than damage.

Mean seed mass per fruit varied from 2.0-6.3 mg (overall mean = 3.75 ± 1.22 mg; c.v. = 32.5%) for the seeds collected in 1982, and from 1.1-6.9 mg (overall mean = 3.93 ± 1.4 mg; c.v. = 35.7%) for the seeds collected in 1984.

The relationship between mean mass per seed and the number of seeds per fruit was defined using Spearman's rank order correlation coefficient for data collected at Gledhow (1982) and at Grandora (1984). A significant negative relationship ($r_s = -0.54$, $p < 0.001$) was found for the 1982 data with a tendency for mean seed mass to decrease as the number of seeds per fruit increased. A significant relationship was not found for the 1984 data ($r_s = -0.25$, $p > 0.05$); the data were extremely variable. Despite the significant relationship determined for the 1982 data, the association between the two variables was not strong and the trend for mean seed mass to decrease as seed number increased was not a consistent, well-defined pattern in the Saskatoon.

Individual seed masses were not measured in 1982, but were in 1984 (Table 3). These data provide some indication of within-fruit and among-fruit variability in seed mass. For fruit with ≥ 2 seeds, the seed mass within fruit tended to be fairly constant and the magnitude of variation (heaviest/lightest seed) was relatively small, ranging from 1-2.48. The magnitude of variation for seed mass between fruit ranged from 1.52 to 6.27, with a tendency to decrease as the number of seeds per fruit increased. Individual seed masses varied from 1.1 to 6.9 mg, the overall magnitude of variation being 6.27 (Table 3).

Discussion

Shoot Morphology and Inflorescence Production

The dimorphic shoot structure described for the Saskatoon is typical of other woody angiosperms including various birch species (Kramer and Kozlowski 1979), apples, pears and related species (Teskey and Shoemaker 1978). In both apples and pears, it is the short shoots that bear the fruit and these shoots must be 2 years old or more in order to bear (Teskey and Shoemaker 1978). Similarly, in the Saskatoon, it is the short shoots that bear fruit, although it is not known at what age they first produce fruit. Previous studies of source-sink relationships in the apple (Hansen 1977; Ferree and Palmer 1982; Forshey and Marmo 1985), and sampling of pest populations on the apple (Lord 1968), have recognized and emphasized the short shoot as a well-defined morphological unit and an integral physiological unit. Consequently, it was not unreasonable to consider the Saskatoon as being similar to the apple from these perspectives.

Anthesis

The Saskatoon is a typical temperate woody plant with respect to the cycle of flower and fruit production, as described by Jackson and Sweet (1972). The production of fruit and seed requires two seasons of development and growth. The determination of floral primordia, and therefore the formation of a floral bud, occurs in the first season and it is not until the following spring that anthesis and fruit development occur. The initiation of the process of flower determination occurs in early July and is complete in late summer (unpublished observation). For any given fruit crop, therefore, the process of flower determination is dissociated from the process of fruit and seed maturation by a period of dormancy; additionally, two separate reproductive episodes overlap, the maturation of the current year's crop of fruit and the initiation of the next crop.

The dates of anthesis for the populations studied are typical for the species in Saskatchewan (Looman and Best 1979). The Saskatoon can be considered a "mass-flowering species", that is, a

TABLE 3. Within- and among-fruit variability of individual seed masses for 43 fruits; Grandora 1984.

	Number of seeds/fruit				
	1	2	3	4	5
Number of fruit examined	21	11	5	3	3
Range of seed mass	1.1-6.9	1.5-5.8	1.4-5.2	2.9-4.4	1.9-4.6
Mean within-fruit magnitude of mass variation*	6.27	1.16	1.73	1.23	1.30
(range)	—	(1-2.19)	(1.03-2.48)	(1.13-1.38)	(1.09-1.64)
Among-fruit magnitude of mass variation*	6.27	3.87	3.71	1.52	2.42

*magnitude of mass variation = heaviest/lightest seed

species characterized by anthesis occurring over a relatively short period of time and involving a very large number of flowers (Heinrich and Raven 1972; Augspurger 1980; Stephenson 1982). Data for the period of anthesis of single ramets and/or clones of the Saskatoon are not available, but observations indicated that most flowers are open at one time. The significance of mass-flowering is often associated with reproductive success for obligate outbreeding species, isolating mechanisms, energetics of pollinators, pollinator attraction, and seed predator avoidance (Augspurger 1981). The significance of mass-flowering to the Saskatoon has not been established and requires further study.

During the course of this study, the dates of peak anthesis were found to vary over a 2½ week period in mid to late May. Such variability is not unusual. Tydeman (1964) observed that the date of full bloom of the apple cultivar, "Cox's Orange Pippin", varied from the 15th April to the 23rd May over a 43-year period, depending on temperature. It is known that bud break and development in the Saskatoon are dependent upon the accumulation of heat units (Junttila et al. 1983), with anthesis following bud break, presumably by a relatively constant time.

In taxonomic references (Looman and Best 1979; Moss 1959), the inflorescence of the Saskatoon is described as a raceme, the sequence of anthesis usually being acropetal. Wyatt (1982) indicates that a raceme is an indeterminate type of inflorescence. However, it is likely that the inflorescence of the Saskatoon is a typical determinate or closed inflorescence where the terminal or center flower opens first, and the lateral flowers open later (Westwood 1978). This has been verified by Steeves and Steeves (1990).

With respect to flower longevity, the values from the current study are similar to those found by McKay (1973) for other species in the genus *Amelanchier* (3-5 days). Data for other species (Primack 1985) suggest that flowers of the Saskatoon are relatively short-lived (a mean of 3.5 days compared to a published range of 1 to 30 days for a wide variety of plant species). This is apparently typical of prairie species where flowers last an average of 2 days (Parrish and Bazzaz 1979). In general, flower longevity is shorter in self-compatible species (such as the Saskatoon) with the probable consequence of decreased levels of outcrossing (Primack 1985).

Number of Flowers per Inflorescence

The results of the current study indicated that the number of flowers per inflorescence in the Saskatoon was very plastic (maximum CV of 65.5%), this representing a potential 1.6 fold increase or decrease. The number of flowers per inflorescence is considered a plastic character, although not to the same extent as numbers of inflorescences per ramet (Harper 1977). Lloyd et al. (1980) collected data on the number of flowers per inflorescence for 17 species of angiosperms and found that variability was apparently related to the type of inflorescence studied (capitulum, umbel and so on).

The occurrence of a most frequent class of flowers per inflorescence appears to be common. Frequency distributions for the number of flowers per inflorescence in *Asclepias syriaca* and *A. quadrifolia* (Willson and Rathcke 1974; Chaplin and Walker 1982) and *Aesculus sylvatica* (Wyatt 1982) had single modal values.

The reasons for variability in the numbers of flowers produced are unclear. The number of flowers per inflorescence in the Saskatoon does not appear to be genetically fixed within narrow limits. It is unknown if variability at the time of anthesis differs from that at the end of the process of inflorescence development (prior to dormancy) because aborted flower buds were occasionally found. However, flower bud abortions were uncommon and thus it is a reasonable interpretation that the process of inflorescence development is variable. In the apple, variable flower initiation is associated with short internode length, the

application of nitrogen fertilizers, a reduction in water supply, high carbohydrate levels, freedom from shading, warm summer temperatures, and subtending leaf area (Jackson and Sweet 1972).

Seed Production

Number of Seeds per Fruit

The low seed to ovule ratios found for the Saskatoon are not unusual. Wiens (1984) found that it was typical for woody plants to mature only 33% of their potential ovules. In the current study, wrinkled and shrunken seeds were assumed non-viable; seed viability was not determined using tetrazolium or germination tests. Recent data on the germination of over 3000 seeds supports the assumption that shrunken seeds are not viable (personal observations).

The reasons for ovules failing to reach maturity, and the consequent low levels of seed production include resource limitation, pollen availability and quality (Willson and Burley 1983), degree of self-incompatibility (Willson 1983), pollinator activity, and ovule and pollen viability (Williams 1970). Wiens (1984) maintains that seed to ovule ratios are genetically determined. The reasons for low seed number per fruit in the Saskatoon are not known and require further study. The significance of few seed per fruit in the Saskatoon is two-fold; first, total seed production is limited below the maximum potential by factors other than damage, and second, fruit with few seeds do not abort as is common in the apple (Luckwill 1970).

Seed Mass

In terms of individual seed mass, an overall magnitude of variation of 6.27 may not be uncommon. Thompson (1984) reports values ranging from 2.6 to 8.1 for within-plant variation of seed mass for *Lomatium grayi*; among plants, seed mass varied 15.8 fold. Thompson (1984) indicates that studies of individual seed masses show considerable variability, contradicting the usual ecological impression of constancy. The results of the current study were for individual fruits arbitrarily collected from several plants along a transect. The plants from which these fruit were collected were very close in proximity so that environmental differences were probably not significant. The causal basis of this variability requires further study.

The relationship between seed mass and seed number in the Saskatoon is not clear. Because flowering and fruit development in the Saskatoon are relatively synchronous (when considered as separate processes), it would be expected that seed mass would be variable to some degree and very possibly be related to seed number per fruit. It is common for yield components such as seed number and mean seed mass to be negatively correlated. Such developmental plasticity is advantageous in the regulation of seed production, enabling a plant to match seed yield to the available resources (Salisbury 1942; Adams 1967; Johnson and Cook 1968). It should be noted however, that yield components may vary independently, as in 7 species of *Asclepias* studied by Wilbur (1976), and in 3 species of *Sesbania* (Marshall et al. 1985a). Because of their overall larger size and storage capacity, perennial species in general may partially escape the developmental limitations on seed yield which constrain annual species (Primack 1978; Marshall et al. 1985a, b). It is possible, therefore, for yield components such as seed number and mean seed mass to vary independently in some years and to be negatively correlated in other years, as was found for the Saskatoon.

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Spatial Relationships of Syntopic White-footed Mice, *Peromyscus leucopus*, Deer Mice, *P. maniculatus*, and Red-backed Voles, *Clethrionomys gapperi*

RONALD E. BARRY, JR., ALAN A. HEFT[1], and THOMAS E. BAUMMER[2]

Department of Biology, Frostburg State University, Frostburg, Maryland 21532
[1]Present address: Unicorn Lake Work Center, Box 326, Millington, Maryland 21651
[2]Present address: 306 Magnolia Road, Joppa, Maryland 21085

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Peromyscus leucopus, P. maniculatus, and *Clethrionomys gapperi* are locally sympatric in forests of eastern North America. The purposes of a live-trapping study conducted in western Maryland in the summers of 1985 and 1986 were to 1) examine the dynamics of spatial relationships among these rodents in rocky habitat, and 2) assess the roles of competition and microhabitat selection in the distribution patterns of these rodents. *Peromyscus leucopus noveboracensis* and *P. maniculatus nubiterrae* were negatively spatially associated at ground level for much of the study. *P. maniculatus* and *C. gapperi gapperi* were positively spatially associated in 1986. Numerical association suggested that competition was especially strong between *P. leucopus* and *P. maniculatus* when population densities remained consistently high. At higher densities, differences between *P. leucopus* and *P. maniculatus* in preference for rock cover contributed to spatial segregation, and preferences of *P. maniculatus* and *C. gapperi* for the rockiest microhabitats resulted in their positive association. Rocks at macrohabitat scale promoted high densities of all three species and contributed to their coexistence.

Key Words: *Peromyscus leucopus*, White-footed Mouse, *Peromyscus maniculatus*, Deer Mouse, *Clethrionomys gapperi*, Red-backed Vole, spatial relationships, competition, microhabitat selection, spatial association, numerical association, habitat fragmentation, Maryland.

Peromyscus leucopus (the White-footed Mouse), *P. maniculatus* (the Deer Mouse), and *Clethrionomys gapperi* (the Red-backed Vole) are sympatric over considerable portions of their ranges in eastern North America (Hall 1981) where they coexist locally in wooded habitats (Miller and Getz 1977a, 1977b; Wolff and Dueser 1986). The two *Peromyscus* would appear to be potential competitors because of overlap in food habits (Wolff et al., 1985), breeding seasons (Wolff 1985), and nest sites (Wolff and Hurlbutt 1982). Nevertheless, Wolff et al. (1983) concluded that *P. l. noveboracensis* and *P. m. nubiterrae* were intra- and interspecifically territorial in woodland habitats in southwestern Virginia. However, Barry et al. (1984) found evidence for spatial segregation along the substrate and vertical stratification of these taxa in Virginia. Similarly, Parren and Capen (1985) found that *P. l. noveboracensis* and *P. m. gracilis* were negatively associated at ground level in forested Vermont habitat, and Drickamer (1987a) found the same relationship between these mice in Massachusetts. Smith and Speller (1970) earlier found that these two subspecies reduced competition in an Ontario woodlot by differential use of ground- and tree-holes.

Getz (1969) found no evidence that interspecific aggression played a major role in the ecological segregation of *P. leucopus* and *C. gapperi* in New England. Wolff and Dueser (1986) suggested a noncompetitive coexistence of *C. gapperi* with *Peromyscus* spp. in Virginia on the basis of extensive habitat overlap. Even where they exist side-by-side, little competition between syntopic *Peromyscus* and *Clethrionomys gapperi* would be expected because of significant behavioral and ecological differences between these taxa (see summary in Wolff and Dueser 1986).

Spatial relationships of small mammals of eastern forest ecosystems are of considerable interest and importance to the understanding of competition and interactions of these animals with their physical environment. Few investigators (*see* Crowell and Pimm 1976; Hallett and Pimm 1979; Dueser and Hallett 1980; Hallett et al. 1983) have simultaneously assessed the effects of competition and microhabitat selection on the spatial distribution of syntopic small mammals in such systems. Spatial relationships among syntopic *Peromyscus* spp. and *C. gapperi* appear to vary with geographic location, habitat, time, and taxa (subspecies). The simultaneous use of space by all three species where they coexist in eastern forests has only recently received attention. From studies by Parren and Capen (1985) and Wolff and Dueser (1986), it appears that extensive substrate rock

cover could promote the coexistence of syntopic *Peromyscus* spp. and *Clethrionomys gapperi* in eastern deciduous forests.

We identified a rocky habitat where abundant ground refugia and potential nest sites existed, and preliminary investigation revealed high densities of mice, as an ideal site on which to monitor spatial relationships within and among populations of *P. leucopus noveboracensis, P. maniculatus nubiterrae* and *C. gapperi gapperi.* The purposes of our study were to (1) examine the dynamics of spatial relationships among these syntopic taxa, and (2) assess the roles of competition and microhabitat selection in the local distributions of these rodents.

Study Area and Methods

Field work was conducted from 22 May-15 August 1985 and 19 May-7 August 1986 in a wooded site at an elevation of approximatley 600 m on the Allegheny Plateau near Frostburg, Maryland, Allegany County (latitude 39° 38′; longitude 78° 56′). Predominant woody vegetation consisted of Sugar Maple (*Acer saccharum*), hickories (*Carya* spp.), American Basswood (*Tilia americana*), grapes (*Vitis* spp.), Witch Hazel (*Hamamelis virginiana*), Black Cherry (*Prunus serotina*), Red Oak (*Quercus rubra*), and Black Locust (*Robinia pseudoacacia*). Important vegetative ground cover included Virginia Creeper (*Parthenocissus quinquefolia*), Poison-ivy (*Toxicodendron radicans*), Jack-in-the-pulpit (*Arisaema atrorubens*), and Blackberry (*Rubus allegheniensis*).

A 10 × 10, one-hectare, live-trapping grid (100 traps), with a trap interval of 10 m, was established at ground level on a site with 76% claystone rock cover. The site was bordered within 75 m on the north by a private paved road, within 50 m on the south by Interstate Route 48, and on the east and west by wooded habitat. Sherman live traps (7.7 × 9.0 × 23.0 cm) were baited with peanut butter. Captured individuals were identified (Feldhamer et al. 1983; Barry et al. 1984) and their sex, age (juvenile, subadult, and adult after Osgood 1909), and reproductive condition recorded, although the data were not partitioned by these categories for analysis. Mice were marked by toe- and ear-clipping and released for subsequent recapture.

The entire trapping period was divided into three trapping episodes encompassing 1000, 1200 and 1200 trap-nights in 1985 and 1200 for each of three periods in 1986. We were able to partition the summers into series of intervals of short duration for separate quantitative analysis because of relatively high densities on our study grid. This is advantageous because of the small amount of absolute time encompassed during any single trapping interval, thus reducing the confounding effects of transcience and shifts in centers of activity for any single analysis. Spatial relationships revealed by such analysis should reflect more closely actual interactions between individuals of the three species.

The minimum number alive (MNA) of all species was used to estimate population density for each trapping episode (Hilborn et al. 1976), and capture frequency at each trap station provided an index to the use of the substrate by each species. Compliance of sex ratios to 1:1 was determined with χ^2 analysis.

Spatial associations were assessed with the χ^2 test of association to analyze presence/absence data of the species at trap stations. Also, home ranges of resident individuals (those captured at three or more locations during any trapping interval) were plotted, and species segregation was further assessed by examining intrasexual, intra- and interspecific home-range overlap (Wolff et al. 1983). Home ranges were defined for each trapping interval by the conservative minimum boundary method (Stickel 1954) because of the restricted period of time encompassed by each interval. Percent intrasexual, intraspecific home-range overlap was determined with the use of the Model 1224-1 Numonics Electronic Graphics Calculator by measuring the proportion of the total home-range area occupied by individuals of one sex and species in which overlap of individuals occurred. Percent intrasexual, interspecific home-range overlap was determined by measuring the proportion of the total area occupied by same-sex individuals of two species in which interspecific overlap occurred. This was done for all combinations of two species.

Tests for numerical associations among small mammal species relied on Pearson product-moment correlation analysis of capture frequencies of the species among the trap stations. Pearson-product moment correlation matrices were constructed to reveal mouse-habitat associations. Habitat variables quantified at each trap station for correlation analysis included: (1) distance from the trap to the nearest stem (DTNS); and within a 2-m radius of each trap location, the (2) number of stems $\geq$ 10 cm in circumference immediately above root swell (STEM), (3) number of logs $\geq$ 10 cm in circumference (LOG), (4) number of rocks with one or more dimensions of $\geq$ 10 cm (ROCK), (5) number of stumps $\geq$ 10 cm in circumference immediately above root swell and $\leq$ 2 m in height (STMP), (6) total basal tree and stump circumference (BTSC), (7) total log circumference (TLC), (8) percent rock cover (to the nearest 10% based on eye-calibration) (RKCV), and (9) percent ground vegetative cover (to the nearest 10% based on eye-calibration) at $\leq$ 1 m in

TABLE 1. Minimum number of *Peromyscus leucopus (Pl), P. maniculatus (Pm),* and *Clethrionomys gapperi (Cg)* known to be alive (MNA). M = number of males of the MNA.

	Trapping Periods					
	1985			1986		
	1	2	3	1	2	3
Pl	34(18M)	41(29M)	38(31M)	47(25M)	57(34M)	33(21M)
Pm	19(10M)	21(16M)	12(9M)	26(11M)	29(16M)	23(14M)
Cg	16(9M)	8(4M)	15(11M)	32(19M)	24(14M)	14(11M)

height (GRVG). Variables were assessed in June of each year. Separate analyses were conducted for all trapping intervals in both summers.

Results

Population Statistics

One hundred ninety-five *P. leucopus* were captured a total of 1017 times, 88 *P. maniculatus* 471 times, and 96 *C. gapperi* 241 times. Population densities were greatest for all three species in 1986 (Table 1). More male (69) than female (33) *P. leucopus* were captured ($p < 0.01$) in 1985. More male (40) than female (19) *C. gapperi* were caught ($p < 0.05$) in 1986.

Spatial Association

In general, short-term distributions of captures were clumped (i.e., patchy) by species. Spatial associations were not apparent between any pairs of species in 1985 when captures for the entire summer were analyzed. However, the two peromyscines exhibited negative association during trapping episodes 1 ($\chi^2 = 12.41$, d.f. = 1, $p < 0.01$) and 3 ($\chi^2 = 5.23$, d.f. = 1, $p < 0.05$) (Figure 1).

In 1986, *Peromyscus maniculatus* and *C. gapperi* were positively spatially associated ($\chi^2 = 9.92$, d.f. = 1, $p < 0.01$) when captures from the entire summer were analyzed. These species were positively associated ($\chi^2 = 14.55$, d.f. = 1, $p < 0.01$) during trapping period 2 (Figure 2). *Peromyscus maniculatus* and *P. leucopus* were negatively associated during intervals 1 ($\chi^2 = 22.16$, d.f. = 1, $p < 0.01$) and 2 ($\chi^2 = 9.38$, d.f. = 1, $p < 0.01$).

Because of relatively high trap mortality and the transient status of *C. gapperi,* data on home-range overlap involving this species are insufficient for

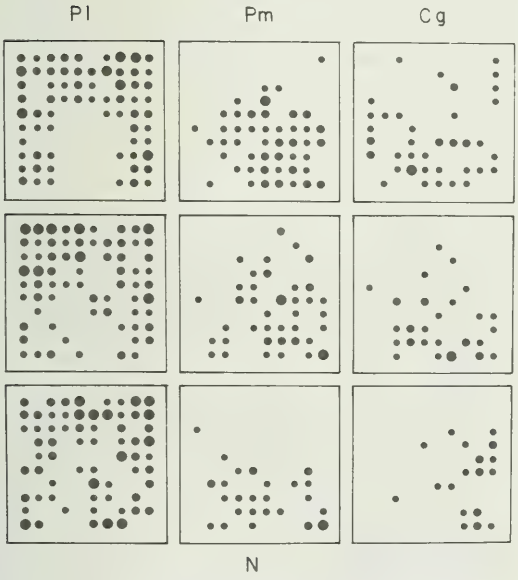

FIGURE 1. Distribution of captures of *Peromyscus leucopus (Pl), P. maniculatus (Pm),* and *Clethrionomys gapperi (Cg)* on the trapping grid during intervals 1, 2 and 3 (top to bottom) in the summer, 1985. N = north. • = 1-2 captures; ● = 3-5 captures; ● > 5 captures.

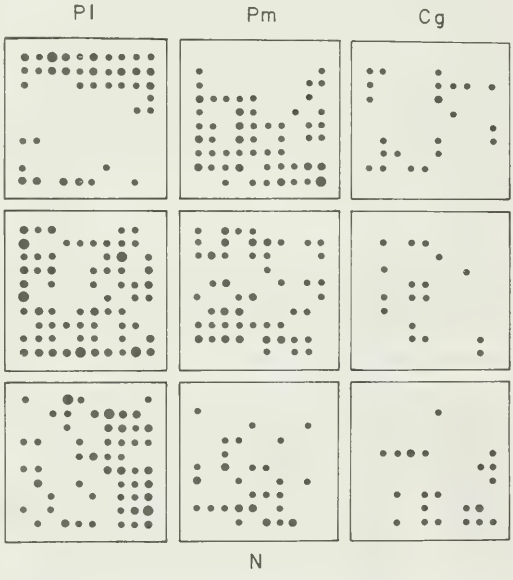

FIGURE 2. Distribution of captures of mice on the trapping grid during intervals 1, 2 and 3 (top to bottom) in the summer, 1986. See Figure 1 for legend.

TABLE 2. Percent intrasexual intra- and interspecific home-range overlap of resident *Peromyscus (see* Table 1 for species legend). Fractions indicate the number of residents that overlapped. Blank spaces indicate ≤ 1 resident (i.e., no possibility of overlap).

	Trapping Periods					
	1985			1986		
	1	2	3	1	2	3
Pl males	8.6	47.3	8.3	14.3	8.6	3.5
	(4/6)	(6/11)	(4/10)	(8/11)	(7/12)	(4/11)
Pm males	8.2	44.5	0.0	0.0	1.9	0.0
	(5/8)	(10/10)	(0/3)	(0/4)	(2/6)	(0/2)
Pl-Pm males	7.9	36.8	9.9	6.6	5.9	1.7
	(5/14)	(17/21)	(5/13)	(7/15)	(7/18)	(3/13)
Pl females	0.0	2.0		0.0	0.0	2.7
	(0/5)	(2/6)		(0/6)	(0/6)	(2/9)
Pm females	6.7	0.0		7.6	4.8	
	(2/4)	(0/3)		(5/7)	(3/6)	
Pl-Pm females	0.0	7.0		1.1	3.4	
	(0/9)	(2/9)		(2/13)	(3/12)	

analysis. Overlap within or between the two *Peromyscus* rarely exceeded 10% during individual trapping periods (Table 2). Nearly as much inter- as intraspecific overlap of home ranges occurred. The amount of intra- and interspecific overlap among females was especially small over the duration of the study, presumably due at least in part to the smaller number of resident females. The amount of intra- and interspecific overlap among male *Peromyscus* increased dramatically during the second trapping interval in 1985 when resident densities were greatest.

In the summer of 1985, only two mice — one male and one female *P. maniculatus* — were captured during all three trapping intervals. In 1986 at higher densities, five *P. leucopus* (three males and two females), five *P. maniculatus* (two males and three females), and one female *C. gapperi* maintained home ranges on the grid throughout the summer.

TABLE 3. Correlation matrix of relationships between capture frequencies of *Peromyscus maniculatus (Pm), P. leucopus (Pl),* and *Clethrionomys gapperi (Cg)* and microhabitat variables (see text for explanation) for the summer, 1985.

Habitat Variables	Species *Pm*	*Pl*	*Cg*
DTNS	0.01	-0.07	0.08
STEM	-0.24*	-0.07	-0.06
STMP	-0.08	0.01	-0.15
BTSC	-0.12	-0.11	-0.10
LOG	-0.10	-0.18	0.01
TLC	-0.03	-0.21*	-0.08
ROCK	0.23*	-0.06	0.23*
RKCV	0.09	-0.06	0.27*
GRVG	0.18	0.08	0.11

*$p < 0.05$

Numerical Association

Peromyscus leucopus and *P. maniculatus* were negatively numerically associated during trapping intervals 1 (r = -0.27, d.f. = 98, $p < 0.01$) and 2 (r = -0.25, d.f. = 98, $p < 0.05$) in 1985. These two species were negatively numerically associated during all three trapping periods (r = -0.41, d.f. = 98, $p < 0.01$; r = -0.33, d.f. = 98, $p < 0.01$; r = -0.24, d.f. = 98, $p < 0.05$; respectively) in 1986. *P. maniculatus* and *C. gapperi* were positively numerically associated during intervals 2 and 3 (r = 0.23, d.f. = 98, $p < 0.05$; r = 0.20, d.f. = 98, $p < 0.05$; respectively) in 1986. Also, *P. leucopus* and *C. gapperi* were negatively numerically associated during trapping periods 1 and 2 (r = -0.26, d.f. = 98, $p < 0.01$; r = -0.22, d.f. = 98, $p < 0.05$; respectively) in 1986.

Habitat Associations

Capture frequencies of *Peromyscus maniculatus* and *Clethrionomys gapperi* were positively correlated with variables reflecting rock cover at trap stations in the summer, 1985 (Table 3). This was due especially to the associations between the number of rocks and these two species during trapping interval 3 (Table 4). *P. maniculatus* was negatively associated with the number of stems at trap stations in 1985 (Table 3), largely due to the strength of this relationship in trapping interval 1 (Table 4). Capture frequency of *Peromyscus leucopus* and TLC were negatively related in 1985. Also, an inverse relationship existed between *P. leucopus* and the two "rock cover" variables during trapping interval 1.

As in 1985, capture frequencies of *P. maniculatus* and *C. gapperi* were positively related to the number of rocks at trap stations in 1986 (Table 5). This was the case for two of the three trapping intervals for each of these species. *P. maniculatus*

TABLE 4. Correlation matrix of relationships between capture frequencies of *Peromyscus maniculatus (Pm), P. leucopus (Pl),* and *Clethrionomys gapperi (Cg)* and microhabitat variables for three trapping intervals (see text for explanation) in the summer, 1985.

Habitat Variables	Interval 1			Interval 2			Interval 3		
	Pm	*Pl*	*Cg*	*Pm*	*Pl*	*Cg*	*Pm*	*Pl*	*Cg*
DTNS	0.09	-0.19	-0.04	-0.12	0.06	0.20*	0.06	-0.05	0.03
STEM	-0.23*	0.13	-0.01	-0.10	-0.06	-0.09	-0.14	-0.18	-0.01
STMP	-0.02	-0.11	-0.02	-0.17	0.08	-0.12	0.05	0.03	-0.14
BTSC	-0.09	-0.13	-0.06	-0.12	0.03	-0.15	-0.01	-0.14	-0.01
LOG	0.01	-0.15	-0.02	-0.13	-0.19	-0.05	-0.08	-0.02	0.06
TLC	0.00	-0.17	-0.09	-0.09	-0.13	-0.01	0.04	-0.12	-0.03
ROCK	0.20*	-0.29†	-0.08	0.03	0.14	0.11	0.26*	-0.04	0.37†
RKCV	0.11	-0.23*	0.16	0.00	0.00	0.16	0.08	0.07	0.18
GRVG	0.05	0.01	0.14	0.16	0.13	0.06	0.15	-0.01	0.00

*$p \leq 0.05$
†$p < 0.01$

was also positively related to percent rock cover during trapping interval 1 (Table 6). In contrast, *P. leucopus* captures and the two "rock cover" variables were negatively correlated (Table 5). This relationship was consistent throughout the summer for the number of rocks (Table 6). *C. gapperi* and the number of stems and BTSC at trap stations were negatively related (Table 5).

Discussion

Peromyscus leucopus was the dominant small mammal on the grid during both years of the study. Because males comprised a greater proportion than females of the populations of *P. leucopus* in 1985 and *C. gapperi* in 1986, spatial relationships within and among the three species depended disproportionately on interactions or associations between males.

The distributions of captures (Figures 1 and 2) of mice of the three species changed through both summers. Also, few individuals remained on the grid throughout the summer. Clearly, the spatial relationships of the three species were dynamic. Nevertheless, periods of spatial segregation between *P. leucopus* and *P. maniculatus* were persistent. This is not consistent with the relationship between these two species (same subspecies) observed by Wolff et al. (1983). They found no spatial segregation between these two species; in fact, individuals of the two species existed side-by-side in their study and behaved essentially as one by exhibiting intra- and interspecific territoriality. In both their study and ours, little intra- and interspecific overlap of home ranges of *P. leucopus* and *P. maniculatus* occurred, suggesting spatial isolation of individuals independent of species designations. However, in our study, individuals were clumped by species, with captures of *P. leucopus* and *P. maniculatus* usually concentrated in different parts of the grid (see Figures 1 and 2).

Drickamer (1987a) found that *P. l. noveboracensis* and *P. m. gracilis* were negatively associated at ground level and exhibited different macrohabitat associations. He suggested that these differences could represent differential responses to habitat features or direct interaction between the species. Our study implicates a role for both microhabitat selection and competition in the distribution patterns of *P. l. noveboracensis* and *P. m. nubiterrae* in Maryland, especially at high densities. Spatial and numerical association suggested that these two species were competing (Dickman and Woodside 1983). Moreover, consistent relationships over the two years between the three species and rock cover, despite short-term shifts in local distributions, attest to the importance of microhabitat selection in their distributions. Species and habitat associations were stronger at higher densities in 1986.

TABLE 5. Correlation matrix of relationships between capture frequencies of *Peromyscus maniculatus (Pm), P. leucopus (Pl),* and *Clethrionomys gapperi (Cg)* and microhabitat variables (see text for explanation) for the summer, 1986.

Habitat Variables	Species		
	Pm	*Pl*	*Cg*
DTNS	0.07	0.00	0.12
STEM	-0.12	0.03	-0.23*
STMP	-0.18	0.09	-0.10
BTSC	-0.01	-0.19	-0.20*
LOG	0.11	-0.04	-0.13
TLC	-0.04	-0.06	0.04
ROCK	0.32†	-0.43†	0.33†
RKCV	0.19	-0.21*	0.14
GRVG	-0.12	0.08	0.07

*$p \leq 0.05$
†$p < 0.01$

TABLE 6. Correlation matrix of relationships between capture frequencies of *Peromyscus maniculatus (Pm), P. leucopus (Pl),* and *Clethrionomys gapperi (Cg)* and microhabitat variables for three trapping intervals (see text for explanation) in the summer, 1986.

Habitat Variables	Interval 1			Interval 2			Interval 3		
	Pm	*Pl*	*Cg*	*Pm*	*Pl*	*Cg*	*Pm*	*Pl*	*Cg*
DTNS	0.09	-0.02	0.16	-0.03	0.04	0.09	0.11	-0.02	-0.05
STEM	-0.16	0.09	-0.27†	0.00	0.06	-0.14	-0.12	-0.07	-0.03
STMP	-0.21*	0.18	0.03	-0.18	0.09	-0.07	0.01	-0.04	-0.18
BTSC	-0.09	-0.08	-0.16	-0.01	-0.18	-0.17	0.13	-0.17	-0.04
LOG	0.01	-0.12	-0.09	0.24*	-0.07	-0.11	-0.01	0.07	-0.05
TLC	-0.11	-0.10	0.16	0.12	-0.14	-0.05	-0.11	0.07	-0.06
ROCK	0.43†	-0.30†	0.11	0.09	-0.35†	0.30†	0.21*	-0.34	0.27†
RKCV	0.25*	-0.12	-0.01	0.13	-0.22*	0.13	0.02	-0.14	0.18
GRVG	-0.06	0.05	0.11	-0.18	0.12	0.10	-0.02	0.01	-0.10

*$p < 0.05$
†$p < 0.01$

Additional differences in habitat associations (e.g., relative to woody stem density, size and species) implicate a role for microhabitat selection in the local distributions of these mice (Barry, unpublished). Microhabitat partitioning commonly is suggested as a mechanism for coexistence of syntopic *Peromyscus* (e.g., *see* Etheredge et al. 1989).

Miller and Getz (1972, 1973, 1977b) reported that the primary factor influencing the local distribution of *C. gapperi* in New England was the amount of available cover in the form of fallen trees and logs, brush piles, and rocks. *C. gapperi* and *P. maniculatus* were positively spatially and numerically associated in Maryland in 1986, owing in part to their similar affinities for sites with numerous rocks. This is partially consistent with the finding of Wolff and Dueser (1986) that *C. gapperi* and *Peromyscus* exhibited considerable habitat overlap in Virginia; they concluded that the distribution of the former was largely dependent on active selection of rocky microhabitat. However, these investigators considered *P. leucopus* and *P. maniculatus* together on the basis of the absence of a difference between the two in habitat use on their grids. The results of several studies, unlike those of our study, have suggested negative associations between *C. gapperi* and *P. maniculatus*. For example, Crowell and Pimm (1976) observed that *C. gapperi* displaced *P. maniculatus abietorum* on an island in Maine. Also, Vickery (1981) found that *C. gapperi* and *P. maniculatus gracilis* differed in the use of evergreen cover in summer. The overlap between these two species in their use of two-dimensional space in Maryland relies on their shared affinity for rocky microhabitat and differential use of other resources stemming from fundamental ecological and behavioral differences between them.

The results of numerical association analysis suggest that *P. leucopus* and *C. gapperi* may have been competing through much of the summer of 1986. However, this analysis may represent a biproduct of different microhabitat affinities or their differences in association with *P. maniculatus*.

The conservative estimate of home range afforded by the minimum boundary method, the trap interval, and the short duration of each trapping period undoubtedly contributed to the small degree of home-range overlap. However, the home ranges of the few resident mice captured in all three intervals in either summer were small (the largest being 800 m^2, that of a *P. maniculatus* female) and exhibited little interspecific (4.2% between *Peromyscus* females, 0.0% between *Peromyscus* males) and no intraspecific overlap in 1986.

The extensive rock cover was a significant factor in the spatial relationships of the mice on our study grid. It was responsible for two-dimensional habitat fragmentation and undoubtedly contributed to the small sizes of home ranges of the three species by providing unusual amounts of cover. Despite the avoidance of microsites with the greatest number of rocks (which may have been due to the high numbers of *P. maniculatus* associated with such sites), *P. leucopus* relied on rocks to a considerable extent for escape cover (Barry, *unpublished*), and probably ground nest sites. Barry and Francq (1980) also found an upper threshold of rock cover for *P. leucopus* in the absence of a congener in New Hampshire. It is apparent that the extensive rock cover in our study area promoted high densities of mice and contributed significantly to their coexistence at the macrohabitat level, despite the differential response by the two *Peromyscus* at the microhabitat level.

Activity and dispersion patterns and spatial relationships of small mammals of eastern forest ecosystems likely rely heavily not only on competitive interactions and microhabitat selection but also such factors as predation, foraging

strategies, microclimate selection, temporal isolation (*see* Drickamer and Capone 1977; Drickamer 1987b), and parasitism. Too, individuals captured may be drawn to trap locations by features outside the small area immediately surrounding the traps. Additional attention needs to be afforded the issue of scale in determining the importance of micro/macrohabitat preference in the local distribution of small mammals (*see* Morris 1984).

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Above-ground Biomass Allocation by Four Understory Vascular Plant Species in Central Alberta Jack Pine, *Pinus banksiana*, Forests*

MICHAEL S. ROSS[1] and GEORGE H. LA ROI

Department of Botany, University of Alberta, Edmonton, Alberta T6G 2E9
[1]Present address: Ecosystem Research Unit, National Audubon Society, 115 Indian Mound Trail, Tavernier, Florida 33070

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Biomass allocation to sexual reproduction and shoot growth was assessed over the 1985 growing season in four important southern boreal understory species in typical 40- and 90-year old *Pinus banksiana* forests on sand dunes. *Arctostaphylos uva-ursi* and *Vaccinium vitis-idaea*, early-successional plants which are important fruit producers for birds and mammals, allocated a higher proportion of new biomass to reproduction in the younger stand. Conversely, *Linnaea borealis* and *Maianthemum canadense*, abundant late-successional species, allocated more biomass to sexual reproduction in the older stand. Fruit production in sub-populations of all four species was highly correlated with floral bud production, and less so with flower:bud and fruit:flower ratios. New reproductive and vegetative biomass were negatively correlated in *A. uva-ursi* and *V. vitis-idaea* sub-populations, positively correlated in *L. borealis*, and uncorrelated in *M. canadense*, suggesting that optimal growing conditions vary among life history states as well as species.

Key Words: Jack Pine *Pinus banksiana*, Bearberry *Arctostaphylos uva-ursi*, Dry-ground Cranberry, *Vaccinium vitis-idaea*, Twinflower, *Linnaea borealis*, Wild Lily-of-the-Valley, *Maianthemum canadense*, biomass allocation, boreal forest, food supply, life history, sexual reproduction, succession, vegetative growth.

Long-lived plants of stable, resource-limited, forest understory habitats generally allocate far more of their resources to maintenance and vegetative expansion than to sexual reproduction (Grime 1979). In such habitats, successful seedling establishment is sporadic, depending on fortuitous combinations of conditions and events, and clonal expansion is probably the major mode of population maintenance (Jackson et al. 1986). Nevertheless, sexual reproduction is ubiquitous among vascular plants of the undisturbed forest understory, and provides an important food source (pollen, nectar, seeds and fruits) for herbivorous animals.

Over most of the Boreal Forest Zone of North America (Rowe 1972), areas disturbed by extensive crown fires or frequent localized surface or ground fires are very common (Heinselman 1973; Rowe and Scotter 1973). Sexual reproduction contributes to the revegetation of areas denuded by fire and other disturbances, by seed inputs from undisturbed populations, and/or from surviving seedbanks and seed-producing clones in the disturbed areas.

Despite the relatively small annual investment in sexual reproduction made by most boreal understory plants, this allocation could serve to maintain genetic diversity *via* gene recombination, thus enhancing the survival of populations (Antonovics and Ellstrand 1984) and fitness of individuals (Lloyd 1980a) in both disturbed and undisturbed areas, as well as to sustain important pollen and seed vector animals. Thus our first objective was to investigate the allocation of new above-ground biomass to reproductive and vegetative parts by four important understory vascular plant species in two contrasting boreal forest habitats, i.e., early- and mid-successional *Pinus banksiana* Lamb. (Jack Pine) forest. In order to determine whether allocation patterns were similar for species characteristic of the same and different successional stage, we studied two species which achieve maximum shoot cover in young pine stands, and two which are more abundant in mature pine stands and persist after Jack Pine has been replaced in the forest canopy by *Picea glauca* (Moench) Voss (White Spruce) and *Abies balsamea* (L.) Mill. (Balsam Fir).

Allocation of plant resources to sexual reproduction is not a simple transaction, but rather a sequential investment in the development of buds, flowers and fruits, whose numbers decrease

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through a variety of development and mortality factors as the growing season progresses. The initiation, survival and development of floral buds through the flower and fruit stages may be controlled by external factors and/or the allocational limits of the plant. If external factors (e.g., unfavorable weather, lack of pollinators, predation) do not reduce the number of reproductive units to a level supportable by available resources, then internal mechanisms (e.g., abortion, decrease in fruit size) may function to do so (Lloyd 1980b; Stephenson 1981; Casper 1984). Differences in the reproductive outputs of species and stands can be more easily interpreted if stage-specific mortality rates of reproductive development are known. Accordingly, our second objective was to determine whether mortality rates of reproductive structures in a species differ significantly between younger and older Jack Pine stands. We did this by censusing floral buds, open flowers and mature fruits during one growing season.

Study Area

Observations were made around two permanent 50 × 50 m reference stands established in 1980 as part of a long-term study of dynamic changes in forest structure and function in the Southern Boreal Subzone (Ahti et al. 1968) of central Alberta (*La Roi and Ostafichuk 1982**). The two stands are 3 km apart near Hondo, Alberta (55°4′N, 114°30′W), ca. 60 km SE of Lesser Slave Lake. Both occupy N-S-trending dune complexes embedded in peatlands west of the Athabasca River. They are typical examples of early and late stages of post-fire succession on the PICEA GLAUCA [PINUS BANKSIANA]/LINNAEA BOREALIS [ARCTOSTAPHYLOS UVA-URSI] habitat type (*sensu* Daubenmire 1968) [seral dominants in brackets], which is common on sandy soils in the study area (*La Roi and Ostafichuk 1982*).

Stand *Y* ("Young") is one of many young Jack Pine/lichen woodlands in the area; its understory is dominated by evergreen dwarf shrubs and caribou lichens (*Cladina* spp.). The tree canopy is 9-14 m tall and stage age is about 40 years, although several older survivors of the stand-initiating fire remain. Tree density is low (924 stems > 2.5 cm dbh/ha) due to a series of surface fires between 1950 and 1972 (*Ross et al. 1986b*) and to browse by hare and deer. Hence the canopy is quite open (cover = 7% (Table 1)) and the forest floor has wide diurnal and seasonal ranges of light, temperature and moisture.

Stand *M* ("Mature") represents a more advanced successional stage in the development of Jack Pine forests in the study area in which the warm-dry-open tree/dwarf shrub/caribou lichen structure has been replaced by a cool-moist-closed tree/tall shrub/forb/feather moss structure. Stand age is 90 years, dominant trees are 20-26 m tall, tree density is 1168 stems/ha, and estimated tree cover is 17%. A survey of fire scars revealed no evidence of fire since 1942 (*Ross et al. 1986b*). A patchy subcanopy of White Spruce is present (2-6 m tall, 3% cover), having developed since the last surface fire. Thus Stand *M* has an older, taller and more densely stocked tree stratum and, consequently, a more shaded forest floor environment than Stand *Y*. Black Bears and Man find much more late summer fruit in Stand *Y* than *M*.

Materials and Methods

Species Descriptions

The species chosen for study were *Arctostaphylos uva-ursi* (L.) Spreng. (Bearberry), *Vaccinium vitis-idaea* L. (Dry-ground Cranberry), *Linnaea borealis* L. (Twinflower), and *Maianthemum canadense* Desf. (Wild Lily-of-the-Valley). The first three are evergreen dwarf shrubs (though only the first has measurable secondary wood) and the last is a summergreen perennial forb. All are locally abundant across the Middle and Southern Boreal Subzones of North America (La Roi 1967), and all can be dominant among the species comprising the lowest vascular plant stratum of *Pinus banksiana* forests on sub-xeric sandy sites in the study area (Table 1).

Arctostaphylos uva-ursi (Ericaceae) is often the leading understory vascular plant in open pine/lichen woodlands, particularly in relatively exposed locations with calcareous soils. In older, more shaded pine stands, it usually has low overall cover but can be locally abundant as nearly pure patches in sunlit areas near canopy openings. *Vaccinium vitis-idaea* (Ericaceae) is a close ecological associate of *A. uva-ursi* (both produce red fruits), but is more abundant on less exposed microsites. It frequently grows on decaying wood, and is quite extensive on such substrates in older pine/feather moss communities. *Linnaea borealis* (Caprifoliaceae) is usually the leading understory vascular species in climax forests of the P. GLAUCA [P. BANKSIANA]/L. BOREALIS [A. UVA-URSI] habitat type, but is most abundant in mature pine/feather moss communities, forming extensive mats on the forest floor. In pine/lichen woodlands *L. borealis* is restricted to moist depressions and other protected microsites, where it grows with feather mosses.

*Author dates in italics are citations of unpublished documents noted separately after Literature Cited.

TABLE 1. Abundance of four understory vascular plant species in four stands chosen to represent different successional stages in the PICEA GLAUCA [PINUS BANKSIANA]/LINNAEA BOREALIS [ARCTOSTAPHYLOS UVA-URSI] habitat type (*La Roi and Ostafichuk 1982*). Cover values are mean percent shoot cover in 25 5 × 5 m plots in August 1983 (*La Roi et al. 1987*). Ranks are based on cover of all vascular plants, excluding tree species.

Stand Age (yrs)	40[a]		60		90[b]		135	
Dominant Tree Species	*Pinus banksiana*		*Pinus banksiana*		*Pinus banksiana*		*Picea glauca Abies balsamea*	
Total Tree Shoot Cover	7		8		17		41	
Species	Cover	Rank	Cover	Rank	Cover	Rank	Cover	Rank
Arctostaphylos uva-ursi	14.7	1	11.6	1	0.8	11	—	—
Vaccinium vitis-idaea	6.0	2	5.6	3	2.1	5	tr	21
Linnaea borealis	0.7	9	0.8	10	5.1	3	1.0	1
Maianthemum canadense	1.3	3	1.5	5	2.7	4	0.1	5

[a]Stand *Y* (see text).
[b]Stand *M* (see text).

Maianthemum canadense (Liliaceae), a rhizomatous perennial forb, is widely distributed in *P. banksiana* stands of all ages in the study area. Unlike *A. uva-ursi* and *V. vitis-idaea*, it is also abundant, though less so than *L. borealis*, in climax forests of the habitat type (Table 1).

Field Procedures

In early May 1985, 1 × 1 m plots were established just outside the borders of the two reference stands. Plot selection was random with two conditions: (1) the plots for each species were distributed evenly around the perimeter of the reference stand; and (2) species were relatively abundant in the plots in which they were to be monitored (i.e., at least 1% July shoot cover for *L. borealis* and *M. canadense*, 3% for *A. uva-ursi* and *V. vitis-idaea*). Five plots were chosen per species per stand; in several plots more than one species was monitored.

Plots were inspected at weekly intervals to determine the developmental stages of the four species. When productions of peduncles, floral buds, open flowers, or mature fruit were complete within a plot, those structures were counted and recorded. Flowers that had already opened at the time of the bud census were included in the bud count; flowers that had shed their petals by the time of peak flowering were counted with open flowers. Because of possible predation of early-developing reproductive structures, such censuses are conservative estimates of total production. Simultaneously with the bud, flower and fruit counts, samples of these modules were collected from outside the plots, bulked by species across stands, counted, oven-dried at 65°C for four days, and weighed. Peduncles were collected and weighed at the same time as buds.

In mid-August, the shoots of the monitored plants of the four species in the 1 × 1 m plots were harvested, separated into 1985 and pre-1985 stems and leaves, oven-dried, and weighed. At that time, 1985 shoots on the three evergreen shrubs were still distinguishable from older shoots on the basis of color and terminal bud scale scars.

Data Treatment

Three variables were derived from the plot census data on each species monitored in each stand: (1) the average number of buds per inflorescence, (2) the proportion of buds that developed into open flowers (flower:bud ratio), and (3) the proportion of open flowers that developed into mature fruit (fruit:flower ratio). In addition, the number of floral buds produced per 100 g of pre-1985 shoots was determined for the three shrub species; for the herbaceous *M. canadense*, bud production was expressed per m^2 ground area.

Biomass of reproductive tissue was estimated by summing the following four components: (1) the number of bud-bearing peduncles multiplied by the mean species weight of peduncles collected outside the plots, (2) the number of buds which did not develop into flowers multiplied by the mean species weight of floral buds, (3) the total number of flowers multiplied by the mean species weight of flowers, and (4) the total number of mature fruits multiplied by the mean species weight of fruits.

To compare productions of unequal-sized subpopulations of the three shrub species, biomass invested in their leaves, stems, and reproductive parts over the 1985 season was expressed as g/100 g of pre-1985 shoot biomass, and are hereafter referred to as "leaf production", "stem production", and "reproductive output", respectively. The

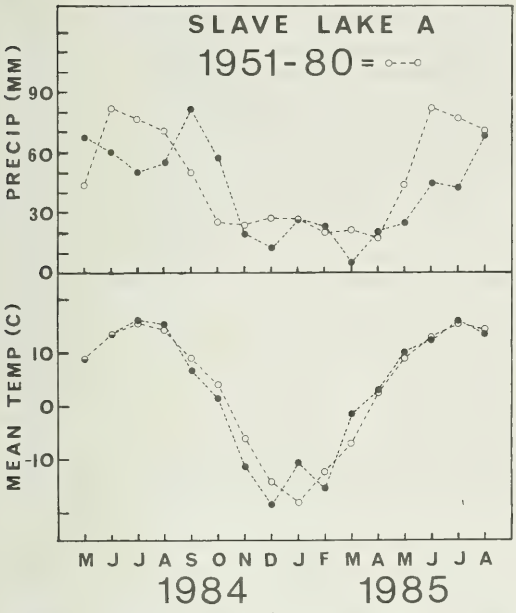

FIGURE 1. Monthly mean air temperatures and total precipitation amounts at the Slave Lake A weather station for the period May 1984 through August 1985, compared with 1951-1980 normals. Data from Environment Canada.

ratio of reproductive biomass to the sum of the three biomass components was termed "reproductive index". We recognize that "pre-1985 biomass" includes 1985 radial increment to older stems. However, secondary radial growth is limited in these prostrate shrubs (particularly *V. vitis-idaea* and *L. borealis*), and should not obscure species or site differences in biomass allocation.

For *M. canadense*, leaf and stem production and reproductive output were expressed on an areal basis as g/m^2 ground area. For such summergreen forbs, "reproductive index" is equivalent to "reproductive effort" or "reproductive allocation" as used by many other researchers for herbaceous plants (ratio of dry weight of reproductive tissue to that of total above-ground shoot biomass: Abrahamson and Gadgil 1973; Silvertown 1982).

Results

1984-1985 Weather Data

Figure 1 compares air temperatures and precipitation for the 16-month period ending in August 1985 with long-term 1951-1980 normals for Slave Lake A, the weather station nearest to the study area. The summer of 1984 was very close to normal in air temperature; rainfall was above-normal in May but below-normal in June-August (summer deficit = 43 mm). The winter of 1984-1985 was at first colder and then warmer than normal; winter snowfall was 47 cm above normal and total precipitation for September-April was 32 mm above normal. The summer of 1985 was again thermally very close to normal in all four months; rainfall, however, was below-normal in all four months (summer deficit = 96 mm). Thus,

TABLE 2. Mean values of floral bud, flower, and fruit development parameters in four understory species in early- and mid-successional pine stands (Stands *Y* and *M*, respectively) in 1985. Flower:bud and fruit:flower ratios (p) were transformed to arcsin $p^{1/2}$ prior to analysis. Probability of equality (*, $P < .10$; **, $P < .05$; ***, $P < .01$) of stand means (T test) is appended to larger value. Parentheses enclose number of sub-populations, standard error.

Species	Stand	Buds per 100 g Pre-1985 Shoots[a]	Buds per Inflorescence	Flower:Bud Ratio	Fruit:Flower Ratio
Arctostaphylos uva-ursi	*Y*	149*** (5, 14)	4.7 (5, 0.6)	0.65 (5, 0.11)	0.19*** (5, 0.03)
	M	6 (5, 3)	7.2 (1, -)	0.42 (1, -)	0.00 (1, -)
Vaccinium vitis-idaea	*Y*	932 (4, 136)	4.6 (4, 0.6)	0.50 (4, 0.17)	0.32* (4, 0.10)
	M	404 (5, 81)	4.2 (5, 0.4)	0.48 (5, 0.14)	0.09 (5, 0.04)
Linnaea borealis	*Y*	970 (5, 223)	2.0 (5, 0.0)	0.05 (5, 0.03)	0.00 (2, 0.00)
	M	1887 (5, 398)	2.0 (5, 0.0)	0.77*** (5, 0.08)	0.00 (5, 0.00)
Maianthemum canadense	*Y*	107 (5, 15)	20.5 (5, 1.5)	0.14 (5, 0.12)	0.03 (2, 0.03)
	M	181 (5, 20)	19.9 (5, 1.9)	0.55** (5, 0.16)	0.23 (5, 0.13)

[a]Bud densities for *M. canadense* are expressed per m^2 ground area.

TABLE 3. Mean oven-dry weight (mg) of an individual bud, flower, mature fruit, and peduncle of four understory species, based on collections made during the summer of 1985 near Hondo, Alberta.

Species	Bud	Flower	Mature Fruit	Peduncle
Arctostaphylos uva-ursi	2.6	4.1	83.0	6.6
Vaccinium vitis-idaea	2.0	3.8	13.0	4.1
Linnaea borealis	1.3	2.4	0.41	2.6
Maianthemum canadense	0.75	0.72	11.0	5.1

weather conditions before and during the study were about average thermally and somewhat drier than average, but well within the range of variation typical of continental boreal areas.

Reproductive Development

Although within-stand variation was high for all reproductive parameters except buds per inflorescence, the production of buds, flowers, and fruits by all four species in the two stands appears to have been influenced by stand environmental conditions (Table 2).

The reproductive behaviors of *A. uva-ursi* and *V. vitis-idaea* in the two stands were similar in several respects. Both produced more floral buds (non-significant for *V. vitis-idaea*) and had higher fruit:flower ratios in the younger stand. However, bud production in the older Stand *M* was much more reduced for *A. uva-ursi* than for *V. vitis-idaea*, and no *A. uva-ursi* fruits developed from the few flowers produced there. The lower bud production of these two species in Stand *M* resulted from fewer inflorescences, not fewer buds per inflorescence. Thus a typical area of Stand *Y* containing 1 kg of *V. vitis-idaea* shoots would produce 1500 fruits, while a similar area in Stand *M* would produce only 175 fruits. Analogous fruit yields for *A. uva-ursi* were 184 and 0, respectively.

Floral bud production of both *L. borealis* and *M. canadense* in Stand *M* was nearly twice that of Stand *Y*, but the differences were non-significant (Table 2). Similarly, the lower fruit:flower ratio for *M. canadense* in the younger stand was non-significant, while no mature *L. borealis* fruits were observed in either stand. However, the flower:bud ratio for these two species was significantly lower in Stand *Y* than in Stand *M*. The cumulative effect of these losses was that fruit production by *M. canadense* per unit ground area was about 10× greater in Stand *M* than in Stand *Y*. Effects of similar magnitude and direction were observed for *L. borealis*, at least through the flower production stage. Since many immature Twinflower fruits were observed in the sample plots in mid-July, we suspect that an intense August hailstorm may have

TABLE 4. Mean leaf production, stem production, reproductive output (all in g 1985 production 100 g pre-1985 shoots), and reproductive index for four understory species in early- and mid-successional *Pinus banksiana* forests (Stand *Y* and *M*, respectively). Standard errors in parentheses. Reproductive index (p) was transformed to arcsin $p^{1/2}$ before analysis. Probability of equality (*, $P < .10$; **, $P < .05$; ***, $P < .01$) of stand means (T test) is appended to larger value. N = 5 for all populations except *V. vitis-idaea* in Stand *Y*, where n = 4.

Species	Stand	Leaf Production (g/100 g)	Stem Production (g/100 g)	Reproductive Output (g/100 g)[a]	Reproductive Index[b]
Arctostaphylos uva-ursi	*Y*	21.6	5.1	2.5***	0.09***
		(1.5)	(0.4)	(0.3)	(0.02)
	M	35.0**	7.3*	0.02	0.001
		(1.7)	(0.3)	(0.01)	(0.001)
Vaccinium vitis-idaea	*Y*	13.3	2.9	5.1*	0.28*
		(1.7)	(0.5)	(0.8)	(0.11)
	M	34.5**	10.2***	1.6	0.04
		(2.5)	(0.5)	(0.3)	(0.02)
Linnaea borealis	*Y*	71.9	20.3	2.6	0.02
		(4.5)	(1.9)	(0.6)	(0.01)
	M	116.3*	34.8	6.6	0.04
		(9.2)	(3.6)	(1.4)	(0.01)
Maianthemum canadense	*Y*	6.2	2.2	0.11	0.01
		(0.3)	(0.1)	(0.01)	(0.01)
	M	7.2	3.1	0.30*	0.03
		(0.8)	(0.4)	(0.03)	(0.01)

[a]Values for *M. canadense* are g production per m^2 ground area.
[b]Reproductive Index = Reproductive Output/(Leaf + Stem Production).

TABLE 5. Pearson correlation coefficients between reproductive output (g/100 g pre-1985 shoots) and three components of reproductive development for four understory species in 1985. Bud production is density/100 g pre-1985 shoots, and flower:bud and fruit:flower ratios (p) were transformed to arcsin $p^{1/2}$ before analysis. Correlations are based on data pooled from both stands, using only those 1 × 1 m plots in which at least one open flower was observed.

Species	n	Bud Production	Flower:Bud Radio	Fruit: Flower Ratio
Arctostaphylos uva-ursi	6	+0.99***	+0.54	+0.80*
Vaccinium vitis-idaea	9	+0.82***	+0.14	+0.45
Linnaea borealis	7	+0.99***	+0.33	0.00
Maianthemum canadense	7	+0.77**	+0.43	0.00

***P < .01
** P < .05
* P < .10

dislodged the readily detached capsules prior to our final harvest.

Resource Allocation

The weights of peduncle, floral bud, flower, and fruit used to calculate reproductive biomass are listed in Table 3. The mean dry weight of fruit varied by more than two orders of magnitude from the berry-like drupe of *A. uva-ursi* to the tiny capsule of *L. borealis*. The latter's small fruits develop from relatively large flowers, while the large berries of *M. canadense* develop from small flowers. Although buds, flowers, and peduncles of *A. uva-ursi* and *V. vitis-idaea* had similar dry weights, the dry fruits of the former were 6× heavier than those of the latter, suggesting a much higher resource allocation to reproduction by *A. uva-ursi*. However, since *V. vitis-idaea* produced ca. 1500 mature fruits/1 kg shoot biomass cf. *A. uva-ursi*'s production of only 184, its total dry fruit production in Stand *Y* was higher (1.95 g cf. 1.53 g/kg shoot biomass).

In all four species leaf and stem productions were higher in the mature pine stand (Table 4). In contrast, the reproductive outputs and indices of *A. uva-ursi* and *V. vitis-idaea* were higher in Stand *Y*, while those of *L. borealis* and *M. canadense* were higher in Stand *M*. Thus, the proportion of 1985 production allocated to reproductive parts differed between stands for the two species pairs. For both *A. uva-ursi* and *V. vitis-idaea*, the low reproductive indices in the mature stand were caused not only by lower reproductive output, but also by higher leaf and stem production.

For the combined stand data-sets of each ericad species, reproductive output and shoot production (leaves + stems) were negatively correlated (*A. uva-ursi*, $r = -0.66$, $P < 0.05$; *V. vitis-idaea*, $r = -0.71$, $P < 0.05$). For *L. borealis*, shoot production and reproductive output were positively correlated ($r = +0.76$, $P < 0.05$); consequently, its reproductive index differed less between stands than its reproductive output. For *M. canadense*, however, the two productions were uncorrelated ($r = +0.13$, $P > 0.50$).

Reproductive indices for the four species were generally low (Table 4). Except for four populations of *V. vitis-idaea* and three of *A. uva-ursi* (six of these seven in Stand *Y*), reproductive index did not exceed 0.10. Reproductive output varied widely within stands; its coefficients of variation were typically 2-3× greater than those for leaf or stem production.

For all four species, the strongest correlation between reproductive output and the three components of reproductive development was with floral bud production (Table 5); with one exception, correlations with flower:bud and fruit:flower ratios were much lower. These results suggest that the observed variations in reproductive output of these species were largely a function of the number of buds they produced, and that flower and fruit development had only secondary effects. The exceptional correlation was with the fruit:flower ratio of *A. uva-ursi*; Bearberry subpopulations with many floral buds seem to abort significantly fewer fruits.

Discussion

Though based on limited data from two stands, the results of this study do provide insights on biomass allocation by understory vascular plant species in Southern Boreal Forest ecosystems that may prove useful in subsequent research.

A successional chronosequence such as that encompassed by the young and mature *Pinus banksiana* stands we studied at Hondo represents an environmental complex-gradient (*sensu* Whittaker 1967) along which several correlated and probably interdependent limiting factors change over time. For example, the mean amount of photosynthetically active (400-700 nm) radiation reaching the forest floor at mid-summer in

Stand *Y* is approximately 3× that in Stand *M*, and the disparity is even greater when only the critical red (654-664 nm) wavelengths are considered (Ross et al. 1986a). The diurnal and seasonal ranges of air and soil temperature and surface soil moisture content are considerably wider in Stand *Y*, and soil temperatures in it rise much more rapidly in the spring and remain higher throughout the summer (*La Roi et al. 1987*). Available soil N is generally higher in mid-seral than early-seral pine stands in the study area, particularly where *Alnus crispa* (Ait.) Pursh (Green Alder), an N-fixer, is abundant, as it is in stand *M* (*Fyles 1986*). Species responses along this temporally correlated complex-gradient should indicate how well adapted they are to survive, grow, and reproduce at different stages of stand development and postfire succession.

Previous studies of the allocation of plant biomass to sexual reproduction in natural populations arranged along a community development gradient have generally focused on earlier stages of secondary succession. These studies have documented a variety of responses: (1) decreases in reproductive effort (RE) with advancing successional stage (*Solidago rugosa* and *S. speciosa*, Abrahamson and Gadgil 1973; *Rubus hispidus*, Abrahamson 1975; *Polygonum cascadense*, Hickman 1975; *Andropogon scoparius*, Roos and Quinn 1977); (2) increases in RE with advancing successional stage (*Solidago canadensis*, Werner 1979); and (3) no correlation between RE and successional stage (*Solidago canadensis*, Bradbury and Hofstra 1976; *Potentilla recta*, Soule and Werner 1981). Soule and Werner (1981), noting these differences in species patterns, postulated that each species has its own zone of optimal reproduction along that segment of the successional gradient which it normally inhabits. According to this model, species having dissimilar optima might be expected to respond differently within the same range of successional stages.

Our investigation of biomass allocation patterns among four boreal forest understory species yielded reproductive optima that are consistent with their positions in the successional sequence. The two species that are most abundant in early-seral stages (*A. uva-ursi, V. vitis-idaea*) allocated more biomass to reproductive parts in the young pine stand, both in absolute terms and relative to leaf and stem production. In contrast, the relative allocation to sexual reproduction by the two late-seral species (*L. borealis, M. canadense*) was higher in the mature pine forest, although between-stand differences were not significant.

The higher reproductive output of *L. borealis* and *M. canadense* in the older stand probably results from their higher photosynthetic efficiency in that environment. The positive correlation of shoot production with reproductive output among sub-populations of *L. borealis* suggests that conditions favorable for vegetative production also stimulate reproductive output in that species. Light conditions associated with high reproductive effort in two forest herbs (*Aster acuminatus* and *Arnica cordifolia*) were also associated with increased plant size (Pitelka et al. 1980; Young 1983).

In *A. uva-ursi* and *V. vitis-idaea*, however, optimal conditions for vegetative and reproductive processes are apparently not the same, i.e., reproductive output and index were significantly higher in younger stands, while leaf and stem production were higher in older stands. This strong negative association may be partly due to differences in developmental morphology. Unlike the reproductive shoots of *L. borealis*, in which flower buds emerge from the axils of new leaves after vegetative development is nearly complete, those of *A. uva-ursi* and *V. vitis-idaea* bear terminal racemes that develop prior to shoot expansion, and this may limit further vegetative growth. Remphrey et al. (1983) reported that reproductive shoots of Bearberry in Saskatchewan were shorter with fewer leaves than vegetative shoots. Thus vegetative and reproductive functions may compete for a limited number of meristems in late summer of the year prior to expansion, as well as for limited resources, once the character of the meristem has been determined. Watson (1984) postulated that "competition for meristems" may account for negative correlations between growth and flowering in an aquatic plant, *Eichhornia crassipes*. Fitter (1986: 401) has observed that competition between fruit production and annual growth is well known in forest trees.

Several authors have suggested that plasticity in biomass allocation is probably adaptive, especially for species occupying broad ecological niches (Hirschfield and Tinkel 1975; Soule and Werner 1981). If we assume there is no significant genetic variation among study populations, then the four study species (particularly *A. uva-ursi* and *V. vitis-idaea*) exhibited a wide range of phenotypic plasticity in the proportion of biomass allocated to sexual reproduction during the 1985 growing season. This plasticity is environmentally correlated and probably environmentally regulated as well. It should be noted that shade-tolerant diploid and shade-intolerant tetraploid chromosomal races of *A. uva-ursi* have been reported by *Dudynsky (1983)* in Alberta.

The extremely high correlation of floral bud number with reproductive output in all four species (Table 5) indicates that accurate estimates of annual intraspecific variation in reproductive

output can be made from single censuses of floral buds. Floral bud number was also the developmental stage most highly correlated with reproductive output in Michigan populations of *Vaccinium angustifolium* (Pritts and Hancock 1984).

Should site conditions that are optimal or favorable for vegetative growth necessarily be optimal or favorable for sexual reproduction or seedling recruitment as well? In this study we have found evidence that vegetative growth and reproductive output optima are positively correlated in two late-seral species, but negatively correlated in two early-seral species. Moreover, we found little evidence of successful seedling recruitment by any of the four study species in the microsites where their seed production is maximal. We conclude that the answer to our question is no. Life history state optima may be coincident in some species and non-coincident in others; they are not necessarily linked.

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Food Habits of Sympatric Coyotes, *Canis latrans,* Red Foxes, *Vulpes vulpes,* and Bobcats, *Lynx rufus*, in Maine

FRED J. DIBELLO[1], STEPHEN M. ARTHUR[2], and WILLIAM B. KROHN[3]

Maine Cooperative Fish and Wildlife Research Unit, 240 Nutting Hall, University of Maine, Orono, Maine 04469-0125

[1]Present address: RFD 1, Box 2235, Litchfield, Maine 04350

[2]Present address: Maine Department of Inland Fisheries and Wildlife, P.O. Box 1298, Bangor, Maine 04401.

[3]Employee of the U.S. Fish and Wildlife Service.

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We studied food habits of Coyotes (*Canis latrans*), Red Foxes (*Vulpes vulpes*), and Bobcats (*Lynx rufus*) by determining percent occurrence of prey remains in scats collected in two regions of Maine during 1979-1983. Snowshoe Hare (*Lepus americanus*) was a major food of all three predators. White-tailed Deer (*Odocoileus virginianus*) was commonly eaten by Coyotes and Bobcats in winter, and use of deer corresponded with winter severity. Mice (*Peromyscus* spp. and *Napaeozapus insignis*), voles (*Clethrionomys gapperi* and *Microtus pennsylvanicus*), and shrews (*Blarina brevicauda* and *Sorex* spp.) were more common in fox scats than in those of Coyotes and Bobcats. During summer, fruits were common in Coyote and fox scats and absent from Bobcat scats. The prevalence of hare in all three diets suggests that inter-specific competition might occur, especially when hares are scarce. Such competition is likely to be most severe for Bobcats, because they showed the greatest reliance on a single food (hares).

Key Words: Coyote, *Canis latrans*, Bobcat, *Lynx rufus*, Red Fox, *Vulpes vulpes*, food habits, Maine.

In 1979, the Maine Cooperative Fish and Wildlife Research Unit (MCFWRU) began field studies of Coyotes (*Canis latrans*), Red Foxes (*Vulpes vulpes*), and Bobcats (*Lynx rufus*) in Maine because of concerns about the effects of the recently established Coyote population on the other predators and White-tailed Deer (*Odocoileus virginianus*). Several investigators collected data concerning predator food habits (May 1981; Caturano 1983; Harrison 1983; Harrison and Harrison 1984; Major 1983; Major and Sherburne 1987; Halpin 1984; Litvaitis 1984). Our objectives were to summarize those data and identify major foods of each predator, investigate dietary overlap, determine seasonal and yearly patterns of food use, evaluate regional differences, and examine the effects of winter severity on predator food habits.

Study Areas

Coyote, Red Fox, and Bobcat scats were collected during 1979-1983 from 2 areas (Figure 1): Maine's western mountain region, near Pierce Pond (PP), and the eastern coastal region near Cherryfield (CH). The PP area was situated on the heavily forested Moosehead Plateau. Average elevation was 300 m and several mountains exceeded 600 m. Well-drained sites were occupied by White (*Betula papyrifera*) and Yellow birch (*B. alleghaniensis*), and Sugar Maple (*Acer saccharum*). Sites with thin soils or poor drainage were dominated by Red (*Picea rubens*) and White (*P. glauca*) spruce, Balsam Fir (*Abies balsamea*), and Northern White Cedar (*Thuja occidentalis*). Many stands of spruce and fir had recently been cutover or defoliated by Spruce Budworm (*Choristoneura fumiferana*). These areas supported dense stands of regenerating spruce and fir, aspen (*Populus* spp.), raspberries (*Rubus* spp.), or sapling-sized mixed woods (Major 1983).

The CH area was characterized by coastal lowlands and rolling hills up to 350 m elevation (Toppan 1935). Black (*P. mariana*) and Red Spruce, Balsam Fir, and Tamarack (*Larix laricina*) dominated lowland sites, with Beech (*Fagus grandifolia*), Red Maple (*Acer rubrum*), and White and Gray birch (*B. populifolia*) on upland sites (Harrison 1983). Extensive commercial blueberry (*Vaccinium angustifolium*) barrens occurred in the eastern and southwestern portions of the area, and ericaceous/sphagnum bogs occupied most other unforested land.

Annual snowfalls averaged 300 cm at PP and 190 cm at CH; mean temperatures reached lows of -16 and -6° C at PP and CH, respectively (Ruffner 1978). A weighted winter severity index used by the Maine Department of Inland Fisheries and Wildlife (MDIFW; Lavigne 1984; Litvaitis et al. 1986) indicated that, of the four winters during the study, all except that of 1981-1982 were mild in both areas. Winter 1981-1982 was moderate at CH and severe at PP.

FIGURE 1. Location of study areas in western and eastern Maine, 1979–1983.

Methods

Scats were collected from roads, trails, blueberry barrens, and along predator trails in snow. Only scats estimated to be < 2 weeks old (i.e., not extensively dried, bleached, or broken) were collected. Scats were classified according to predator species using associated tracks and the shape, length, and diameter of the scat. Scats were stored frozen, then oven-dried for 36-48 hours at 90°C. Scat contents were examined microscopically and identified by comparison with keys (Marten and Barkley 1961; Adorjan and Kolenosky 1969; Moore et al. 1974) and a reference collection of hairs, bones, and seeds.

We determined the percentage of scats containing each food type (% occurrence) for each of three seasons. Winter (December-April) was characterized by nearly continuous snow cover and minimum daily temperatures consistently below 0°C. During summer (May-August) minimum temperatures were above 0°C and deciduous trees were in leaf. During fall (September-November) temperatures often dropped to about 0°C, but there was little snow cover. We did not consider spring a separate season because of the rapid transition from winter to summer conditions. Within seasons, we compared occurrences of major foods (those with ≥ 20% occurrence in scats of ≥ 1 predator) between study areas using a Bonferroni z statistic (Zar 1984: 396). We used the χ^2 goodness-of-fit statistic to test for seasonal differences in occurrence of major foods by each predator within each area. Because of possible differences in digestibility of foods by different carnivores (Floyd et al. 1978), we made only qualitative comparisons among predators.

Results and Discussion

A total of 3053 scats was collected (2101 Coyote, 500 Red Fox, and 452 Bobcat). Snowshoe Hare (*Lepus americanus*), White-tailed Deer, small mammals (including *Blarina brevicauda, Clethrionomys gapperi, Microtus pennsylvanicus, Napaeozapus insignis, Peromyscus* spp., and *Sorex* spp.), and fruits were the most common foods (Table 1). Frequency of occurrence of foods in scats differed between seasons and study areas for all predators (Figure 2), and samples were not evenly distributed among seasons or areas. Therefore, we analysed the data separately by season and area.

SNOWSHOE HARE

Hares occurred frequently in Bobcat scats throughout the year. However, Coyotes in both areas, and foxes at CH, altered their use of hare seasonally, perhaps because of changes in availability of alternate foods (Coyote: $\chi^2 = 14.03$, $P < 0.001$ [PP], $\chi^2 = 44.59$, $P < 0.001$ [CH]; Red Fox: $\chi^2 = 4.33$, $P = 0.12$ [PP], $\chi^2 = 24.81$, $P < 0.001$ [CH], Bobcat: $\chi^2 = 0.48$, $P = 0.79$ [PP], $\chi^2 = 0.30$, $P = 0.86$ [CH]; Figure 2). Seasonal patterns of hare use by Coyotes varied between areas. At PP use was greatest during fall and least during winter, probably because PP coyotes ate more deer during winter. At CH, hare occurred most frequently in Coyote scats during winter and least frequently during fall, reflecting changes in occurrence of fruit. Feeding on hare by foxes in both areas was lowest during summer, when fruit consumption was high.

Occurrence of hare in Coyote scats in both areas decreased dramatically during the most severe winter (1981-1982), when occurrence of deer increased (Table 2). Although data were limited for foxes and Bobcats, these predators also seemed to eat more large prey during the severe winter (foxes ate fewer small mammals and more hare, while Bobcats ate fewer hare and more deer). The switch from smaller to larger prey might have been due to increased availability of White-tailed Deer, decreased availability of small mammals, restricted mobility of Coyotes and Bobcats compared to that of hares, or a combination of factors.

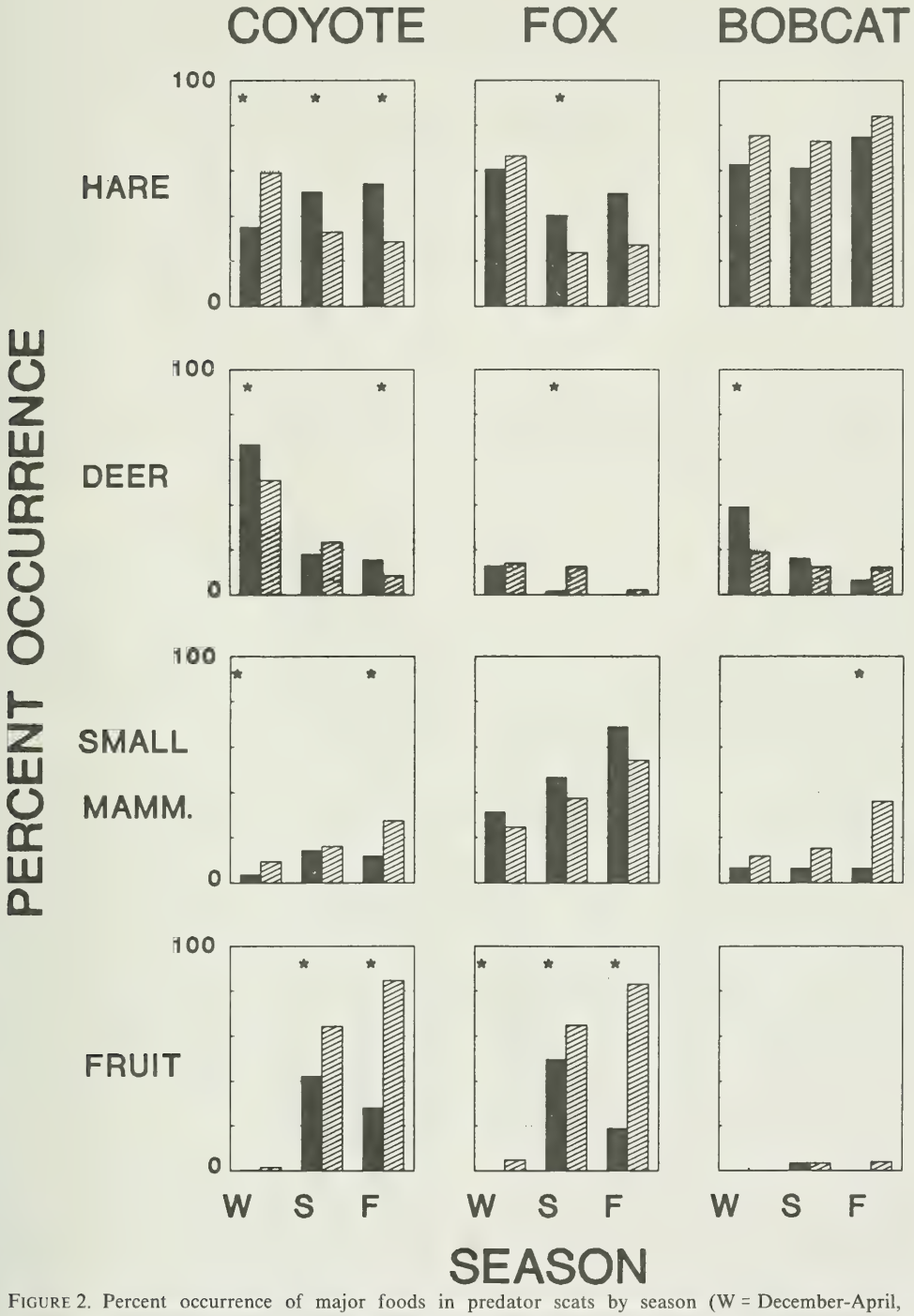

FIGURE 2. Percent occurrence of major foods in predator scats by season (W = December-April, S = May–August, F = September–November) in Pierce Pond (solid bars) and Cherryfield (hatched bars), Maine, 1979–1983. Asterisk indicates a difference between areas with $P < 0.05$.

TABLE 1. Occurrence (%) of food types in scats of Coyotes, Red Foxes, and Bobcats at Pierce Pond (PP) and Cherryfield (CH) Maine, 1979–1983.

	Coyote		Red Fox		Bobcat	
Food	PP	CH	PP	CH	PP	CH
Snowshoe Hare	45.6	38.0	48.5	42.8	64.1	75.1
White-tailed Deer	34.3	27.1	5.7	12.2	27.4	17.3
Small mammals	9.6	17.7	42.4	33.6	6.6	15.0
Fruit[1]	22.7	54.8	28.8	36.5	0.9	1.7
Birds	9.1	5.7	10.9	10.7	8.5	6.6
Vegetation	11.7	17.0	5.7	9.6	7.5	1.7
Red Squirrel[2]	0.1	1.4	3.9	2.6	3.8	2.6
Muskrat[3]	1.4	0.2	1.7	0.4	2.8	2.0
Moose[4]	4.5	0.4	0.4	0.4	2.8	0.6
Insects	3.2	4.2	7.4	8.9	0	0.9
Other mammals[5]	4.8	1.6	1.3	1.5	2.8	2.3
n	934	1167	229	271	106	346

[1]Includes blueberries, raspberries, pincherries, chokecherries (*Prunus virginiana*), serviceberries (*Amelanchier* spp.), apples, beech nuts, and *Aralia* spp.
[2]*Tamiasciurus hudsonicus*
[3]*Ondatra zibethecus*
[4]*Alces alces*
[5]Beaver (*Castor canadensis*), Porcupine (*Erethizon dorsatum*), and Raccoon (*Procyon lotor*).

WHITE-TAILED DEER

Remains of White-tailed Deer occurred in scats of all three predators in both areas. We could not determine whether a predator had killed a deer or fed on carrion. Presumably, adult deer remains in fox scats were from carrion. Halpin (1984) reported that Red Foxes in CH scavenged on deer carcasses.

Use of deer varied seasonally for all predators except CH Bobcats (Coyote: $\chi^2 = 129.96$, $P < 0.01$ [PP], $\chi^2 = 113.70$, $P < 0.01$ [CH]; Red Fox: $\chi^2 = 11.77$, $P < 0.01$ [PP], $\chi^2 = 5.28$, $P = 0.07$ [CH], Bobcat: $\chi^2 = 7.09$, $P = 0.03$ [PP], $\chi^2 = 2.68$, $P = 0.26$ [CH]; Figure 2). Occurrence of deer in Coyote scats was high during winter, with a marked decline in summer and fall. Red Fox and Bobcat scats contained deer less frequently, and occurrence of deer fluctuated less throughout the year, except for a marked increase in occurrence of deer in scats of PP Bobcats during winter.

Severe climatic conditions during winter physically stressed deer and inhibited their movements (Mautz 1978; Severinghaus 1981). This probably made deer more susceptible to predation by Coyotes and Bobcats and increased deer mortality from other causes, which increased the availability of deer carrion. During other seasons, when deer were stronger and more mobile, less carrion was available, and predators used foods that were more easily obtained (Figure 2).

Deer densities were similar in PP and CH (MDIFW unpublished data), yet occurrence of deer in Coyote and Bobcat scats during winter was higher at PP (Figure 2, $z = 2.69$ for Coyotes, $z = 3.11$ for Bobcats, $P < 0.05$). The greater winter severity at PP may have increased both natural mortality of deer and their susceptibility to Coyote and Bobcat predation. In both areas, occurrence of deer in Coyote scats was highest during the most sever winter (Table 2).

During summer, White-tailed Deer fawns occurred in 1.5% of 342 Coyote scats from PP and 2.8% of 532 scats from CH ($z = 0.567$, $P > 0.35$). For all years combined, highest use of fawns by Coyotes was in June, when 22.0% of 36 scats from CH and 10.4% of 48 scats from PP contained fawn remains. Harrison and Harrison (1984) reported that Coyote pups in CH fed primarily on deer from May-July, and they believed that reproductive pairs of Coyotes probably preyed heavily on fawns. During summer, fawn remains occurred in 2.5% of 80 fox scats and 3.9% of 152 Bobcat scats from CH, but were absent from PP scats of both species.

SMALL MAMMALS

During all seasons, occurrence of small mammals was highest in Red Fox scats (Figure 2), increasing progressively from winter to summer to fall ($\chi^2 = 5.00$, $P = 0.08$ [PP]; $\chi^2 = 10.10$, $P < 0.01$ [CH]. This coincided with a period of increased small mammal production beginning in May that produced peak populations during September and October (Smith and Lautenschlager 1978; May 1981; Major 1983).

Snow depth might have reduced the use of small mammals by predators in winter. Halpin and Bissonette (1988) found that frequency of small

TABLE 2. Occurrence (%) of hare and deer in Coyote scats during winter compared to winter severity index (WSI)[1] at Pierce Pond (PP) and Cherryfield (CH) Maine, 1979–1983.

	WSI[1]		Hare		Deer		n[2]	
Winter	PP	CH	PP	CH	PP	CH	PP	CH
1979–1980	42	42	40.4	51.7	57.4	40.0	94	60
1980–1981	53	48	29.7	65.9	52.5	51.3	101	197
1981–1982	109	70	11.7	18.2	75.0	81.8	60	11
1982–1983	44	40	50.0	35.0	64.9	65.0	94	20

[1]WSI < 70 = mild, WSI 70–90 = moderate, WSI > 90 = severe (Lavigne 1984).
[2]Number of scats collected.

mammals in fox scats decreased as snow depth increased, and that foxes relied almost entirely on Snowshoe Hare during periods of deep snow.

FRUITS

Fruits were seasonally important in Coyote and fox diets, but were found in only a small proportion of Bobcat scats (Table 1, Figure 2). Coyotes and foxes at CH consumed fruits throughout the year, feeding on nuts and frozen berries during winter, and they ate fruit more frequently than did PP Coyotes and foxes (Figure 2, $z = 6.45$ for Coyotes, $z = 2.17$ for foxes, $P < 0.05$). Type of fruit consumed also differed between areas, corresponding with differences in availability. Blueberry occurred in 93.3% and raspberry in 2.2% of Coyote scats from CH that contained fruit ($n = 640$). Only 17.5% of 212 Coyote scats from PP that contained fruit had blueberry, but 65.0% had raspberry and 29.7% had pincherry (*Prunus pensylvanica*). In PP, 1.5% of 66 fox scats with fruit contained blueberry, 74.2% contained raspberry, and 6.1% contained pincherry. Conversely, of 99 CH fox scats with fruit, 74.7% contained blueberry, 3.0% contained raspberry, and pincherry was absent. Blueberries were abundant in CH because of extensive cultivated blueberry barrens, whereas wild raspberries were more abundant in PP because of recent logging operations. Use of fruits at PP was highest during summer, when raspberries were most abundant. Use of fruit at CH peaked during fall, reflecting greater use of the later-ripening blueberries.

Conclusions

Because of uncertainties regarding rates of digestion and the proportions of undigestible matter in various carnivore foods, scat contents provide only an approximation of predator food habits (Floyd et al. 1978). However, the importance of Snowshoe Hare as food for Coyotes, Red Foxes, and Bobcats in Maine was obvious. This dietary overlap suggests that interspecific competition for food might occur, at least when hares are scarce. Competition is likely to be most severe for Bobcats, because they were the most specialized of these predators and relied primarily on hare year-round. Coyotes were opportunistic, eating hare throughout the year, but also eating fruits in summer and deer in winter, according to availability. Foxes ate both hare and small mammals throughout the year, and fruits when available.

Major and Sherburne (1987) and Harrison et al. (1989) found that fox home ranges usually were located along the edges of Coyote ranges, and suggested that this was evidence of interference competition. Although Major and Sherburne (1987) found no evidence of interference competition between Bobcats and Coyotes in Maine, exploitation competition for hares might exist. Despite high pelt prices and similar season lengths, the harvest of Bobcats in Maine declined 73% between 1974 and 1985, suggesting a population decline (MDIFW unpublished data). The Coyote population increased dramatically during this period (Hilton 1986), and Litvaitis and Harrison (1989) believed that this was evidence of exploitation competition between the two predators. However, the Bobcat decline cannot be attributed entirely to the Coyote increase because the effects of human harvests were not known, the deer population declined (although this might have been due to coyote predation), and several severe winters occurred during the period (Major 1983; Litvaitis and Harrison 1989).

White-tailed Deer were an important food of Coyotes and Bobcats during winter. The importance of deer relative to other prey probably was greater than the percent occurrence indicated, because scat analysis tends to underestimate the relative weight of large prey eaten by a predator (Floyd et al. 1978). We did not investigate the effects of predation on the deer population, nor could be determine how many deer were killed by predators. However, a model of population dynamics of White-tailed Deer in Maine (Chilelli 1988), incorporating data on predator food habits, suggested that predation was second in importance

only to hunting in determining population size. Predation probably is especially important when severe winter weather restricts deer movements and reduces availability of other predator foods.

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Spawning Time and Fecundity of Northern Redbelly Dace, *Phoxinus eos*, Finescale Dace, *Phoxinus neogaeus*, and their Hybrids in Upper Pierre Grey Lake, Alberta

MRINAL K. DAS and JOSEPH S. NELSON

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

Das, Mrinal K., and Joseph S. Nelson. 1990. Spawning time and fecundity of Northern Redbelly Dace (*Phoxinus eos*), Finescale Dace (*Phoxinus neogaeus*), and their hybrids in Upper Pierre Grey Lake, Alberta. Canadian Field-Naturalist 104(3): 409–413.

Spawning in Northern Redbelly Dace, Finescale Dace, and their hybrids extends from about mid-June to late July at temperatures ranging from 13.0° to 18.0°C in Upper Pierre Grey Lake, Alberta. The relationship of fecundity with length and weight was similar in the two parental species and the hybrids. Diameter of the fully ripe eggs is about 0.91-1.24 ($\bar{X}$ = 1.11) mm in Northern Redbelly Dace, 1.24-1.50 ($\bar{X}$ = 1.37) mm in Finescale Dace, and 0.92-1.58 ($\bar{X}$ = 1.26) mm in the hybrids. The number of eggs ranged from 146-1030 ($\bar{X}$ = 654) in Northern Redbelly Dace, 406-830 ($\bar{X}$ = 565) in Finescale Dace, and 292-1716 ($\bar{X}$ = 730) in the hybrids.

Key Words: Northern Redbelly Dace, *Phoxinus eos*, Finescale Dace, *Phoxinus neogaeus*, hybrids, Cyprinidae, spawning time, fecundity, Upper Pierre Grey Lake, Peace River drainage, Alberta.

Northern Redbelly Dace (*Phoxinus eos*) and Finescale Dace (*P. neogaeus*) hybridize throughout much of their range in North America (Joswiak et al. 1982). A study employing canonical variates and principal components analyses suggests that in Upper Pierre Grey Lake, Alberta, the total *Phoxinus* population comprises approximately 55% Northern Redbelly Dace, 12% Finescale Dace, and 33% all-female hybrids (Das and Nelson 1989). Relatively little information exists on the premating isolating mechanisms (e.g., spawning time, habitat, or behavior) or on their general biology in sympatry. The purpose of this study is to give information on the spawning time and fecundity of the three forms in Upper Pierre Grey Lake.

Study Area

Northern Redbelly Dace, Finescale Dace, and their hybrids were studied in Upper Pierre Grey Lake (53°54′N, 118°34′W). This 40 ha lake of 9 m maximum depth is the second largest in surface area of a complex of five lakes situated about 32 km east of the town of Grande Cache in the boreal forest of the foothills of the Rocky Mountains in Alberta and is part of the Peace River drainage. Three of these lakes, known as Lower, Middle, and Upper Pierre Grey (Figure 1), are managed for a sport fisheries and have stocked Rainbow Trout (*Oncorhynchus gairdneri*) (Lower and Middle) and Brook Trout (*Salvelinus fontinalis*) (Upper). Upper Pierre Grey Lake is surrounded by sloping banks except for the northwest and southeast corners. Surrounding banks are mainly vegetated by Black Spruce (*Picea mariana*) and Lodgepole Pine (*Pinus contorta*), with a few Trembling Aspen (*Populus tremuloides*) and White Spruce (*Picea glauca*). Emergent and submergent vegetation is very sparsely distributed along the narrow littoral zone. Surface water temperatures taken between early June and early August ranged from 11.0° to 19.5°C in 1984 and 13.5°C to 17.0°C in 1985.

The fishes of Upper, Middle, and Lower lakes were poisoned with rotenone in 1969 for fisheries management (Makowecki and Hunt 1975). Longnose Sucker (*Catostomus catostomus*) and Bull Trout (*Salvelinus confluentus*) were eradicated from the Upper Lake. Presently, Brook Trout, a few White Sucker (*C. commersoni*), Brook Stickleback (*Culaea inconstans*), Pearl Dace (*Semotilus margarita*), Northern Redbelly Dace (*Phoxinus eos*), Finescale Dace (*P. neogaeus*), and *P. eos* × *P. neogaeus* hybrids occur in the lake. Brook Trout were introduced in 1969. We assume that the other species presently in the lake either escaped the chemical treatment, invaded the lake on their own from another nearby lake in the low drainage (to the southeast) that was not poisoned, or were introduced (perhaps as bait fish). The first two possibilities have some support from a study of the Brook Stickleback. This species shows marked variation in the pelvic skeleton morphs in the various lakes of the Pierre Grey complex. In contrast to Lower and Middle lakes, most Brook Stickleback in Upper Pierre Grey Lake have a complete pelvic skeleton (Nelson 1977) and did so before the rotenone program (Nelson and Atton 1971) [note: the Lower, Middle, and Upper lakes = Lakes 1, 2, and 3, respectively,

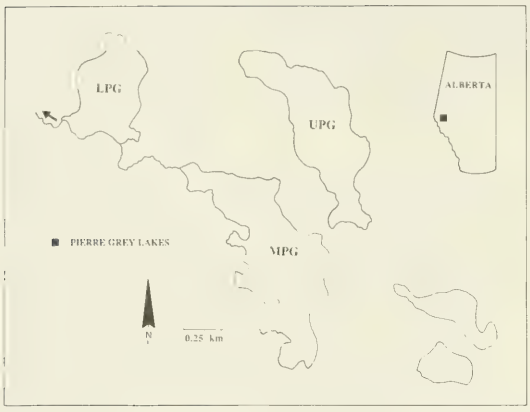

FIGURE 1. Map of the Pierre Grey lakes complex, and their location in Alberta. LPG = Lower Pierre Grey Lake, MPG = Middle Pierre Grey Lake, and UPG = Upper Pierre Grey Lake.

in these publications]. Possible donor lakes that were not poisoned have similar morphs to these lakes. Most sticklebacks in the lake to the southeast of Upper Pierre Grey Lake have complete pelvic skeletons and this small lake has the three species of cyprinids that are in the Upper Lake. Most of those in the lake in a shallow valley to the southeast of Lower and Middle Pierre Grey lakes lack the pelvic skeleton; however, this lake lacks cyprinids and thus could not have been a donor lake.

Methods

Information was obtained on the spawning time and fecundity of the *Phoxinus* complex in Upper Pierre Grey Lake by collecting fish with minnow traps and dip net from 27 May to 17 August in 1984 and from 30 May to 14 August in 1985. The soft clay-like bottom prevented seining.

The time of spawning for each of the two parental species was inferred using three methods. The first method, similar to that used by Nelson (1968), involved a qualitative judgement on the degree of female gonad development using the following criteria: ripe — eggs extruded only under firm manual pressure, near maximum size, creamy yellow color; fully ripe — eggs flow out spontaneously while handling, at maximum size, golden yellow color; spent — few or no mature eggs left in body cavity, abdomen visibly sunken.

The second method was quantitative, although as an index it is relatively crude. The spawning period for each species and the hybrids was followed by determining the percent contribution of female gonads to body weight. Total wet body weight and gonad weight (both sides) were measured in preserved specimens to the nearest of 0.01 g. The gonadosomatic indices (gonad weight × total body weight^{-1}%) of both species and hybrids were pooled for sampling dates and plotted over the spawning period.

In the third method, also quantitative, the mean diameter of 10 freshly extruded and unfixed ova (both ripe and fully ripe) per female was measured using an ocular micrometer. The mean of ova diameters from all such eggs of females of each of the three groups was graphed.

In the study of fecundity, defined as the number of eggs in the female, the gravimetric subsampling method (Bagenal and Braum 1978) was used to determine the female fecundity of 50 Northern Redbelly Dace (39.4-54.5, $\bar{X}$ = 46.8 mm SL), 16 Finescale Dace (46.6-68.7, $\bar{X}$ = 56.4 mm SL), and 30 hybrids (46.6-67.6, $\bar{X}$ = 58.5 mm SL). All ova from one female were divided into two equal parts by weight. Potential fecundity was measured by actual counts of all ova present in one part under a dissecting microscope and multiplied by two. No

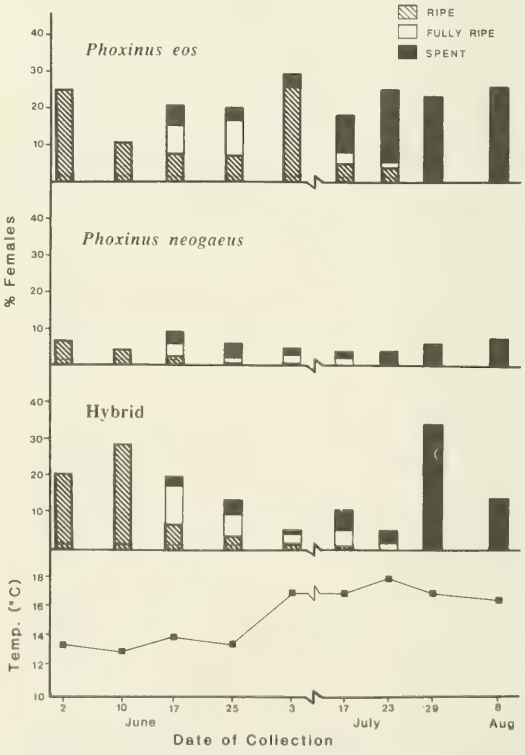

FIGURE 2. Change in female gonad maturity for Northern Redbelly Dace, Finescale Dace, and their hybrids, collected from Upper Pierre Grey Lake, during the spawning period, 1984. x-axis = collection dates; y-axis = % of females in the total population including males and females. Surface water temperatures are also presented.

attempt was made to distinguish immature from mature ova, although both were present in many specimens. Consideration of only mature ova might produce a more meaningful comparison in fecundity studies. The fecundity relationship was described by a regression of logarithm of ova number on both logarithm of standard length and logarithm of body weight using the BMDP6D computer program (Dixon 1983). Analysis of covariance was performed on these data using the BMDP1V computer program.

Results

Spawning time

Based on the degree of gonad maturity, females of both species and the hybrids became fully ripe at about same time in 1984 and 1985 (Figures 2 and 3). Spawning, as inferred from the presence of fullyipe females, extended from about 17 June to about 25 July, when temperatures were between 13.0°C and 18.0°C. Northern Redbelly Dace and hybrid females outnumbered Finescale Dace females in all three gonad states. Male Finescale Dace were uncommon and only two fully ripe males (with freely flowing milt) were caught in 1985 (25 June and 3 July). The first fully ripe male Northern Redbelly Dace was captured on 4 June in 1984 and on 2 June in 1985, and the last such male was captured on 1 August in 1984 and on 29 July in 1985.

The results of plotting changes in the gonadosomatic index of females and ova size are shown for 1985 in Figures 4 and 5 respectively. There is a partial separation in the periods of maximum gonad weight suggesting that most spawning occurs earlier in Finescale Dace and the hybrids than in Northern Redbelly Dace. The eggs of Finescale Dace are much larger (fully ripe eggs are 1.24-1.50 mm in diameter; $\bar{X}$ = 1.37, S. D. = 0.08) than those of Northern Redbelly Dace (fully ripe eggs are 0.91-1.24 mm in diameter; $\bar{X}$ = 1.11, S. .D. = 0.08). Individuals of Finescale Dace are generally larger than those of Northern Redbelly Dace. The hybrid eggs are 0.92-1.58 mm in diameter ($\bar{X}$ = 1.26, S. D. = 0.14). The three means are significantly different from each other at the 95% level. The increase in the mean ova size of Finescale Dace after 17 June and of the hybrids after 3 July is due to the presence of only fully ripe females in the collection, although total gonad weights are less during this period.

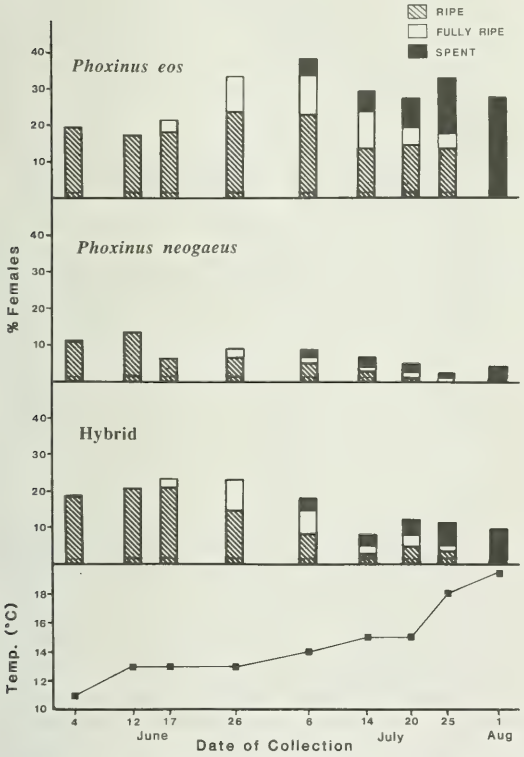

FIGURE 3. Change in female gonad maturity for Northern Redbelly Dace, Finescale Dace, and their hybrids, collected from Upper Pierre Grey Lake, during the spawning period, 1985. x-axis = collection dates; y-axis = % of females in the total population including males and females. Surface water temperatures are also presented.

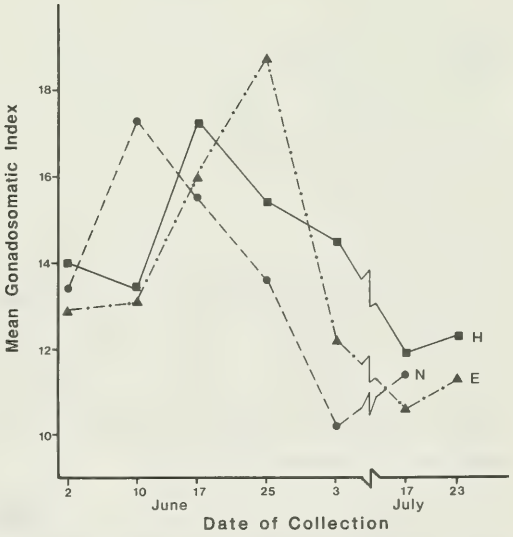

FIGURE 4. Change in gonadosomatic indices (gonad weight × total body weight^{-1}%) of female Northern Redbelly Dace (E), female Finescale Dace (N), and their hybrids (H) sampled from Upper Pierre Grey Lake during the spawning period, 1985. Data represent sample means of gonadosomatic indices.

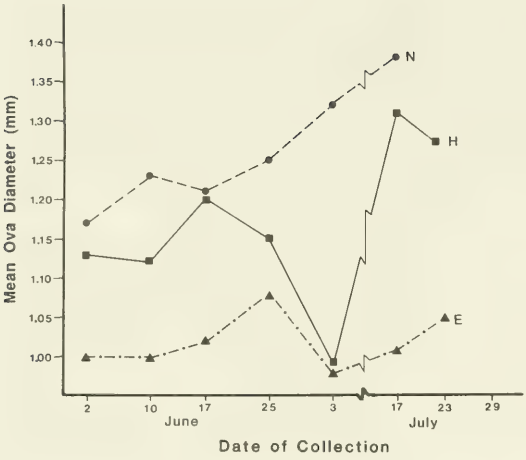

FIGURE 5. Trends in ova diameter during 1985 spawning period for Northern Redbelly Dace (E), Finescale Dace (N), and their hybrids (H) from Upper Pierre Grey Lake. Data represent sample means of ova diameter.

TABLE 1. Analyses of covariance of length-fecundity and weight-fecundity regressions of 50 Northern Redbelly Dace, 16 Finescale Dace, and 30 hybrids from Upper Pierre Grey Lake, 1985.

		F	P
LENGTH-FECUNDITY REGRESSIONS			
P. eos + *P. neogaeus*	intercept	1.511	>0.05
	slope	2.058	>0.05
P. eos + Hybrid	intercept	0.061	>0.05
	slope	1.496	>0.05
P. neogaeus + Hybrid	intercept	2.384	>0.05
	slope	0.089	>0.05
WEIGHT-FECUNDITY REGRESSIONS			
P. eos + *P. neogaeus*	intercept	3.638	>0.05
	slope	6.204	<0.05
P. eos + Hybrid	intercept	1.632	>0.05
	slope	3.835	>0.05
P. neogaeus + Hybrid	intercept	1.889	>0.05
	slope	0.437	>0.05

Fecundity

The relationship of fecundity to standard length for the two species and the hybrids is described by the following equations:

P. eos $\log F = -0.436 + 1.912 \log L$

P. neogaeus $\log F = 2.617 + 0.067 \log L$

Hybrid $\log F = 2.122 + 0.402 \log L$

where F = fecundity and L = standard length. Analysis of covariance shows no significant difference ($P > 0.05$) between the three regressions in either intercepts or slopes (Table 1).

The relationship of fecundity to total body weight is described by the following equations:

P. eos $\log F = 2.509 + 0.931 \log W$

P. neogaeus $\log F = 2.716 + 0.039 \log W$

Hybrid $\log F = 2.683 + 0.269 \log W$

where F = fecundity and W = total body weight. Analysis of covariance shows no significant difference ($P > 0.05$) between the three regressions in intercepts, but shows significant difference ($P < 0.05$) between the slopes of Northern Redbelly Dace and Finescale Dace (see Table 1). There is no significant difference between the slopes of Northern Redbelly Dace and the hybrids and Finescale Dace and the hybrids.

Discussion

The spawning season of Northern Redbelly Dace and Finescale Dace has been studied by many workers. In Michigan, spawning activities of Northern Redbelly Dace commenced in late May and extended to August (Cooper 1935; Hubbs and Cooper 1936). Breeding males of both species were collected in New York in August 1955 and June 1958 (New 1962). In Minnesota, Stasiak (1972) observed a separation of the spawning season between the two species; Finescale Dace were observed spawning in late April and early May, but Northern Redbelly Dace did not begin to spawn until early June. Becker (1983) stated that in Wisconsin, spawning of Finescale Dace occurs from April to June and ripe males and females have been collected in mid-June. He also mentioned that in Northern Redbelly Dace the spawning season extends from the latter part of May into August. In Upper Pierre Grey Lake the peaks of the spawning period for the females of the two species based on the gonadosomatic index occurred at different times (in 1985, 10 June for Finescale Dace and 25 June for Northern Redbelly Dace). This difference thus agrees with differences reported in Minnesota and Wisconsin. However, there is extensive overlap in time during which there are fully ripe females of the two parental species. Temporal isolation is therefore a weak isolating mechanism in preventing hybridization. This, in part, may explain why hybrids are so common in Upper Pierre Grey Lake; however, based on the work of Dawley et al. (1987), the hybrids could represent a self-reproducing clonal population. Spawning for the two species ended by the end of July in 1984 and 1985. The large eggs noted by McPhail and Lindsey (1970), on 24 August for Northern Redbelly Dace in "Pierre Grey Lake" need not suggest that there is a second and late spawning period. However, our sampling did not extend so late into the summer.

Stasiak (1978) gave a range of 2300-6450 eggs for Northern Redbelly Dace from Minnesota. Becker (1983) found 410 ripe eggs in one Northern

Redbelly Dace from Wisconsin. The number of eggs for Northern Redbelly Dace in this study ranged from 146-1030 ($\bar{X}$ = 654) eggs for 50 individuals. Egg counts taken from 20 Finescale Dace from Minnesota ranged from 784-3060 (Stasiak 1978). The number of eggs for Finescale Dace in our study ranged from 406-830 ($\bar{X}$ = 565) eggs for 16 specimens. The ova number of *P. eos* × *P. neogaeus* hybrids has not been previously reported. The number of eggs for the Upper Pierre Grey Lake hybrids ranged from 292-1716 ($\bar{X}$ = 730) for 30 fish. Interestingly, although the mean diameter of the eggs in the hybrids was intermediate to that of Finescale Dace and Northern Redbelly Dace, the mean number of eggs was largest in the hybrids.

Fecundity and body weight relationship for the two parental species show significant difference only in their slopes. Eggs of hybrids appeared to be similar in shape and condition to the parental eggs. Stasiak et al. (1988) reported evidence of hybrid fertility by fertilizing the hybrid eggs with Northern Redbelly Dace sperm. In this study spent hybrids were found, suggesting that they do spawn. Whether these female hybrids in Upper Pierre Grey Lake successfully spawn with the males of parental species or whether they form a self-reproducing clonal population is not known.

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Multiple Strandings of Sowerby's Beaked Whales, *Mesoplodon bidens*, in Newfoundland

JON LIEN[1], FRANCES BARRY[1], KAREN BREECK[2], and ULRIKE ZUSCHLAG[1]

[1]Ocean Studies Centre and Department of Psychology, Memorial University of Newfoundland, St. John's, Newfoundland A1C 5S7
[2]Faculty of Medicine, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3B6

Lien, Jon, Frances Barry, Karen Breeck, and Ulrike Zuschlag. 1990. Multiple strandings of Sowerby's Beaked Whales, *Mesoplodon bidens*, in Newfoundland. Canadian Field-Naturalist 104(3): 414–420.

Two strandings of Sowerby's Beaked Whales (*Mesoplodon bidens*) occurred in Newfoundland; one in 1986 with six individuals and a second stranding in 1987 which involved three whales. These multiple strandings are the first reported from Newfoundland and the western North Atlantic. Results of examination of three mature males from the 1986 stranding and one immature female from the 1987 stranding are presented.

Key Words: Sowerby's Beaked Whale, North Sea Beaked Whale, *Mesoplodon bidens*, Ziphiidae, multiple strandings, Newfoundland.

The genus *Mesoplodon* comprises nine species, most of which are poorly known and generally regarded as rare. Sowerby's Beaked Whales, also known as North Sea Beaked Whales (*Mesoplodon bidens*), are thought to occur in low numbers in the North Atlantic with a distributional range that centres in the North Sea (Moore 1966). Saemundsson (1939) suggested the species is distributed in the open sea and strays to coastal waters from time to time.

There are a total of 30 or so strandings reported for this species on the European coast as well as sporadic sightings there (Saemundsson 1939; Fraser 1953; Oynes 1974; Christensen 1977). Sheldrick (1979) lists 29 stranding records of *M. bidens* on the British coastline from 1913-1972.

In the Western North Atlantic there are only eight recorded strandings and two verified sightings of individual *M. bidens* from Labrador to the Gulf Coast of Florida (Dix et al. 1986; Marion et al. 1988). A single animal abnormally close to shore was repeatedly sighted in Conception Bay, Newfoundland (47° 34′N, 68° 54′W) where it had been entrapped in inshore fishing gear. It was assumed to be the same animal which later stranded nearby (Dix et al. 1986). A group of animals was sighted near Hydrographer Canyon on the southern edge of the continental shelf in 800 fathoms of water in 1987 (Marion et al. 1988).

The first recorded instance of a *Mesoplodon* multiple stranding was that of 28 individuals of *Mesoplodon grayi* on the Catham Islands in 1874. J. G. Mead (Smithsonian Institution, personal communication) has accumulated 12 subsequent records of multiple strandings for *Mesoplodon*: *Mesoplodon grayi* (5), *Mesoplodon layardii* (3), *Mesoplodon stejnergeri* (3) and *Mesoplodon* spp. (1).

Two multiple strandings of *M. bidens* in the eastern North Atlantic have been documented. On 18 April 1957, two *M. bidens* females stranded alive together on the west coast of Norway (Jonsgard and Hoidal 1957). It was speculated that this was a mother-calf pair but no milk was found in the larger whale. Evans (1980) reports three animals that stranded on the Isle of Skye, Scotland, in August 1977. Apart from these reports, there are few hints of the social grouping of *M. bidens*. Oynes (1975) saw a group of 10 animals; Christensen (1977) reports a group of 8-10 individuals; Marion et al. (1988) saw a group of five whales which included adults and young.

In this paper, we report two separate multiple strandings of *M. bidens* which recently occurred in Newfoundland.

Methods

Memorial University maintains a widely advertised toll-free phone line on which strandings of marine mammals can be reported. This has been operating since 1979. Immediately when strandings are reported, a crew is sent to the location to examine the animals and obtain stranding accounts from local observers.

The *M. bidens* that stranded near Carmanville in 1986 were examined on 1 September. The skulls of two Carmanville whales (ID. 1 and 2) and complete skeleton of the other (ID. 3) were collected for the National Museum. of Natural Sciences, Ottawa, Ontario. The Norris Arm whale (ID. 4) was examined on 22 September 1987 and the skeleton collected for the Ontario Science Centre, Don Mills, Ontario

The delay between stranding and examination allowed time for local people to take meat from some of the stranded animals in Carmanville and

Davidsville. The Norris Arm whale had not been disturbed and was intact. These activities, the time between death and examination and the immediate weather and environmental conditions, affected the extent of examination of the dead whales.

Examination procedures as recommended by Myrick (1986) and Hare and Meade (1987) were followed as far as possible; measurements were made following Leatherwood et al. (1982).

Aging of the animals was attempted by both cross and longitudinally sectioning a tooth from each of the four specimens. Using suggestions by Perrin and Myrick (1980), the exposed surfaces were etched with 10% formic acid. Varying the time intervals of acid application was attempted as well as varying the wash times.

An alternative approach of mounting thin sections on glass slides to allow microscopic examination was also used. The teeth were sliced by a diamond blade trim saw. One surface was ground flat using progressively finer grades of grinding powder before being affixed to the slides with glue. Once the tooth was firmly attached, the other side was ground with a diamond grinding wheel. During the examining of the prepared samples under a microscope, a solution of 75:25 ethanol:glycerine was applied to enhance the growth ring readability.

Independent counts of the GLG (growth layer groups) were made from preparations of all the extracted teeth by four observers.

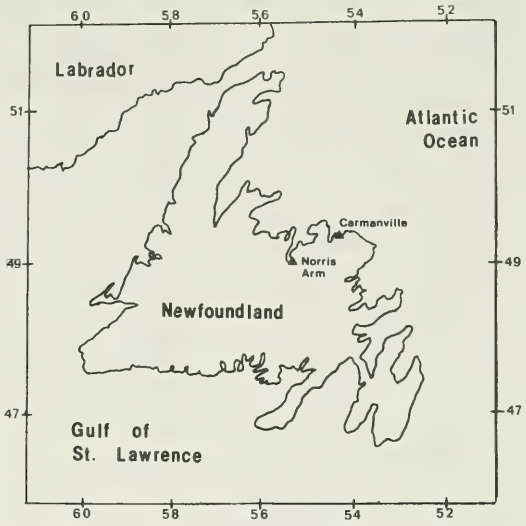

FIGURE 1. Locations of multiple strandings of Sowerby's Beaked Whales (*Mesoplodon bidens*) in Newfoundland.

Results

Stranding Accounts:

Multiple strandings of *M. bidens* occurred near Carmanville and Norris Arm, Newfoundland. Locations of the strandings are shown in Figure 1.

On 29 August 1986, a small group of whales, believed to be "potheads or dolphins" were sighted in the harbor at Carmanville, Newfoundland (49° 24′N, 54° 18′W) (Figure 2). Animals within the group appeared to observers to be all about the same size; none were noticeably larger or smaller than the rest. The whales behaved erratically. Reports stated that the animals at times moved exceptionally rapidly. At other times the whales would move slowly in a closely gathered group. All reports agree that there were a total of six whales in the group.

For most of 29 August the whales appeared to circle together tightly, at times in very shallow water close to shore. In the early afternoon several of the animals stranded; the remainder of the group were in the shallow water just offshore of the stranding. When local people pushed the whales from the shore they rejoined the unstranded individuals offshore.

Throughout the day the whales stranded four or five times and were pushed back into the water. Local officers from the Department of Fisheries and Oceans towed one of the stranded animals well offshore. While being towed, the whale struggled vigorously. Later reports suggest that the whale may have come back to rejoin the group circling in the harbor although we cannot be sure of this.

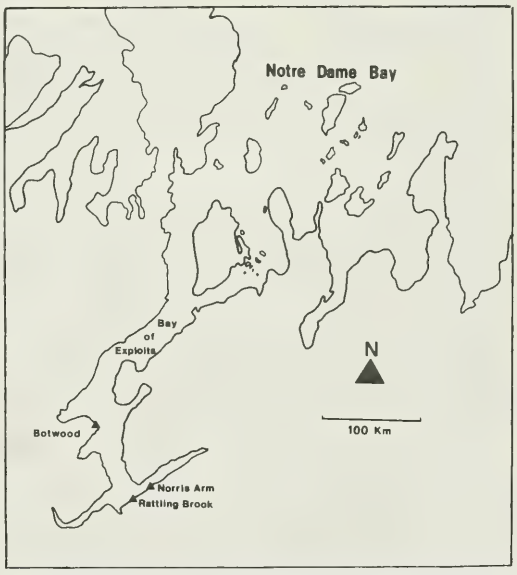

FIGURE 2. Rattling Brook and Norris Arm, Newfoundland. Known stranding locations of *Mesoplodon bidens* are marked.

One animal finally stranded and died later in the afternoon (ID. 1). The group of whales was not seen in the harbor the next morning (30 August). However, around 1000 h, a second whale was seen in Carmanville South (49° 25′N 54° 16′W) where it was observed colliding with a wharf and a large vessel moored there. This behaviour continued until later in the evening. During the night, watchmen aboard the vessel could hear continued collisions with the hull. The early morning on 31 August, this whale (ID. 2) was found dead on a nearby beach with its rostrum badly damaged from the repeated colisions.

On the same day (31 August), a third animal (ID. 3) was discovered dead on a beach in Davidsville (49° 20′N, 54° 26′W) a distance of about 31 km by water from Carmanville Harbor. The exact time of stranding was not known.

On 1 September, all shorelines within 15 km of Carmanville Harbor were searched by boat but no other whales were found. No whales which could resemble the remaining *M. bidens* were reported and we cannot be sure what eventually happened to the other whales earlier seen swimming in Carmanville Harbor.

The second multiple stranding of *M. bidens* occurred a year later in the Bay of Exploits near the community of Norris Arm (49° 07′N, 55° 15′W). On 15 September 1987, a single animal beached itself and was reported to the Department of Fisheries and Oceans. Officers pulled the whale from shore and it appeared to join a small group (estimated at 3-4 animals) of similar-sized whales some distance offshore.

On 16 September, fishery officers in the same area reported that a "strange looking dolphin with a very pointed nose" approached their boat and followed them around for a period of about one hour. The whale spy-hopped, breeched, and appeared very energetic.

There were several reports of 1-3 animals beaching on several occasions between 17 and 18 September. One whale (ID. 4) beached dead near Rattling Brook (49° 04′N; 55° 19′W) on 18 September (Figure 3). This stranding was not reported and verified until 21 September.

There were many sightings of small groups of whales reported between 15 and 22 September in the Bay of Exploits and Norris Arm area. We cannot be sure any of these sightings involved *M. bidens*. We do not know what happened to the two additional animals that stranded.

Results of Examinations:

Cause of deaths on the animals could not be determined. Measurements, heart weight and number of teeth of the four animals examined are presented in Table 1.

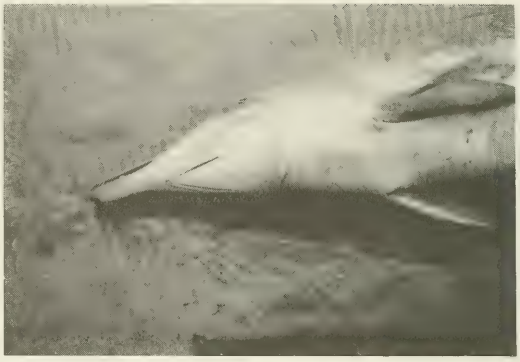

FIGURE 3. *Mesoplodon bidens* female (I.D. 4) from Norris Arm, Newfoundland showing shape of the head, body and pectoral fins and the slits on the lower jaw.

Teeth used for measuring GLGs are shown in Figure 4. The teeth of the three whales from Carmanville (ID.s 1-3) are of mature males; the tooth of the female whale (ID. 4) from the Norris Arm stranding, although it had not erupted, also appears to have an adult tooth shape (Fraser 1953). The presence of GLGs was discernable in both the cross and longitudinal tooth sections. However, even though the acid etching procedure increased the contrast somewhat and thus the distinction between layers, consistent counts were difficult.

Ovaries of the Norris Arm female were small and clearly immature. The three males examined were mature.

Discussion

Reports of *M. bidens* are uncommon and this may indicate that the species is rare. Accounts (Moore 1966) which suggest that distribution of the species centers in the North Sea may stem from the comparative efficiency of stranding reporting networks in different countries (Jonsgard and Hoidal 1957) rather than actual differences in distribution.

Records from eastern Canada (Sergeant and Fisher 1957; Dix et al. 1986) and the present account certainly suggest that the animals frequent western North Atlantic coasts fairly regularly. Stranding report networks have become more efficient in many areas of North America recently, although it is difficult to quantify effort (Geraci and St. Aubin 1979; Lien 1980). Because of the presence of the unusual beak, it is likely that most stranded *M. bidens* would be reported. Since the 1979 inception of the comprehensive network for stranding reports which presently operates in Newfoundland, verified sightings or strandings of *M. bidens* individuals or groups have averaged

TABLE 1. Mensural data state units of measurements of four stranded *Mesoplodon bidens*.

Measure	Carmanville		Norris Arm	
Identification number:	1	2	3	4
Tip of lower jaw to:				
start of V slashes	—	—	—	26
end of V slashes	—	—	—	53
gape of mouth	42	52	52	—
centre of eye	58	62	63	63
anterior insert of pectoral	120	115	111	104
posterior insert of pectoral	—	136	134	117
tip of pectoral	153	163	168	—
umbilicus centre	—	227	—	216
centre genital slit	290	298	315	319
centre anus	337	340	343	336
Tip of upper jaw to:				
centre blowhole	54	63	63	61
anterior dorsal fin	264	288	313	276
point dorsal fin	—	330	342	301
posterior dorsal fin	310	323	351	306
fluke notch	462	485	495	462
Maximum pectoral length	48	51	56	48
Maximum pectoral width	17	17	18	15
Maximum fluke length	—	128	130	98
Maximum fluke width	—	—	—	56
Blowhole width	—	—	—	10
Dorsal fin height	—	21	—	15
Girth at:				
Centre L eye to centre R eye	52	66	—	—
eye	116	115	113	112
anterior insert of pectoral	188	210	—	165
posterior insert of pectoral	—	216	—	199
umbilicus	—	—	—	228
anterior dorsal fin	234	222	—	207
posterior dorsal fin	196	202	—	188
anus	174	164	—	152
Heart weight (g)	4500	3830	4408	—
Length of intestine: stomach to anus	—	—	—	1442
Blubber thickness:				
mid-dorsal	5.2	4.8	5.1	3.68
mid-lateral	4.0	3.2	4.0	—
mid-ventral	4.0	5.0	4.9	3.02
	L R	L R	L R	L R
Tooth count: upper	0 0	0 0	0 0	0 0
lower	1 1	1 1	1 1	1* 1*
Testicle L length	11.8	13.2	13.2	—
weight (g)	138	177	240	—
R length	12.4	15.75	12.21	—
weight (g)	140	191	227	—
Ovaries length	—	—	—	3.14
width	—	—	—	13.75
weight (g)	—	—	—	2.9

*Teeth were embedded and not visible.

0.30/year. this compares to an average of 0.12 sightings or strandings per year based on data for 1947-1973 from Sergeant and Fisher (1957), Sergeant et al. (1970) and Dix et al. (1986). *M. bidens* is a species which is known primarily from stranded specimens. The efficiency of stranding report networks could well bias conclusions about the distribution of the species. Thus, it is not reasonable to conclude that *M. bidens* has become more common in the past decade in Newfoundland. Earlier suggestions that the distribution of *M. bidens* centers in the North Sea and only

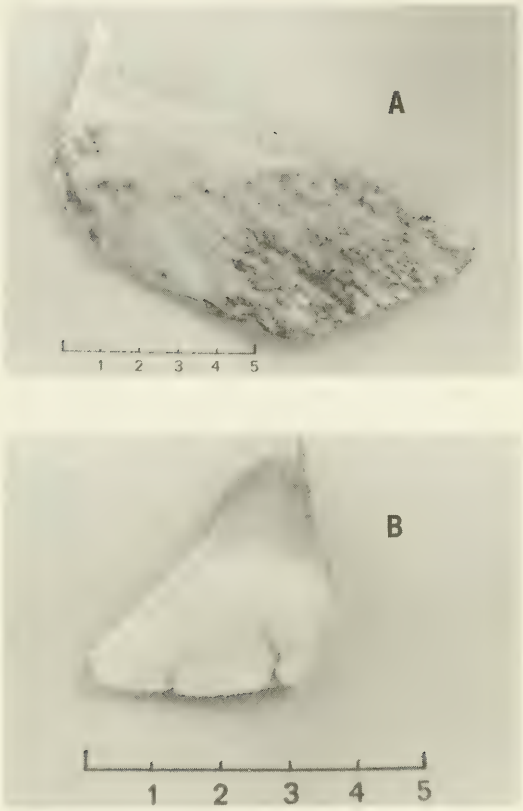

FIGURE 4. Teeth from one adult male (A) and one female (B) of *Mesoplodon bidens*.

occasionally wanders to eastern North Atlantic waters should therefore perhaps be regarded as premature.

Sightings of ziphiids have been most common near the edges of temperature fronts in water depths of about 200 m (Price and Fairfield 1985). The *M. bidens* sighting by Marion et al. (1987) is consistent with these observations but Oynes (1975) sighted the species in waters 1500 m deep and Christensen's (1977) sighting also occurred in deeper water. Sightings of *M. bidens* are so rare it is difficult to evaluate Saemundsson's (1939) contention.

If *M. bidens* is a pelagic species that only occasionally visits coastal waters, one might expect multiple strandings of this species to be more common than if it were a species with a coastal distribution and extensive familiarity with nearshore navigational hazards (Sergeant 1982; Tyack 1987). The two multiple strandings reported here double the total number of such events for this species in the entire North Atlantic.

In the past three decades, the ratio of multiple/single strandings of *M. bidens* on Newfoundland's coast is 2:1. For British shores, the equivalent ratio is 1:29 but Sheldrick (1979) makes the point that multiple strandings are generally considered rare for all species on British coasts. Sergeant (1982) argues that mass strandings seem to occur near the center of a species range rather than at fringes of the range or as extralimital occurrences.

Another species, the Long-finned Pilot Whale (*Globicephala melas*), which is an offshore pelagic species and returns to coastal Newfoundland waters seasonally to feed on squid (Mercer 1975) may be somewhat comparable. From 1957-1980, Sergeant (1982) lists 12 mass strandings of *G. melas* in eastern Canada which estimates a multiple/single stranding ratio of about 1:1. Of course, there may be reason to suspect that strandings of single animals of this species might be less likely reported than would multiple strandings. However, strandings of other coastal species such as *Phocoena phocoena* typically involve single whales.

Sergeant and Fisher (1957) speculate that the inshore occurrence of *M. bidens* in Newfoundland is correlated with abundance of the Short-finned Bait Squid (*Illex illecebrosus*). Dix et al. (1986) noted, however, that strandings of *M. bidens* had all occurred in years when squid abundance was low. The only contents found in the stomachs of stranded *M. bidens* were fish otoliths, probably from the Atlantic Cod, *Gadus morhua*, a prey species which would be available in quantity both offshore and in coastal waters (Dix et al. 1986). There were no squid inshore in 1986 and 1987 when the present strandings occurred. Stomachs of all the mass stranded whales in this report were empty. Thus, the reasons for the inshore occurrence of *M. bidens* in Newfoundland waters are unknown. The relatively higher abundance observed in inshore as compared to offshore waters is most likely attributable to the greater likelihood of sighting the species in inshore waters.

Group sizes of the four known multiple strandings of *M. bidens* are 2 (Jonsgard and Hoidal 1957), 3 (Evans 1980), 3 and 6 individuals in this report. The number of individuals in groups of *M. bidens* sighted is also low, ranging from 3 (Reiner 1986) to 10 (Christensen 1977) individuals. Thus, Gaskin's (1982) conclusion that ziphiids are generally found as single individuals or in small groups is probably correct for *M. bidens*.

Groups may also be segregated by size, age or sex. In the present report, animals within both the Norris Point and Carmanville stranding groups were reported to be about the same size. That all males were obtained from the pod in Carmanville is unusual. The probability of randomly sampling all males (N = 3) from a group (N = 6) which is composed of equal numbers of males and females

is low (P = 0.05). Thus it is possible that *M. bidens* may form all male social groups. The 1957 Norwegian stranding of two females (Jonsgard and Hoidal 1957) may have been a mother and offspring or, alternatively, a female group.

The female compares in length to a pregnant female of 483 cm harpooned by fishermen and examined by Reiner (1986). Although the Norris Arm, Newfoundland, specimen was slightly shorter, it was larger in girth and its ovaries were clearly those of an immature female. Males examined were all mature. Variation between geographic areas in size at maturity seems a distinct possibility.

Acknowledgments

We thank James G. Mead of the Smithsonian Institution for his encouragement and advice, and for information from his files on multiple strandings of *Mesoplodon*; Brooks Bath and Harold Blackwood for assistance with field work; Fred Thornhill of the Earth Science workshop at Memorial University for thin sectionning the teeth; and Garry Stenson of Fisheries and Oceans for his suggestions and advice.

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Population Density and Home Range Characteristics of Woodchucks, *Marmota monax*, at Expressway Interchanges

SUSAN M. WOODWARD

Department of Mammalogy, Royal Ontario Museum, 100 Queen's Park Crescent, Toronto, Ontario M5S 2C6

Woodward, Susan M. 1990. Population density and home range characteristics of Woodchucks, *Marmota monax*, at expressway interchanges. Canadian Field-Naturalist 104(3): 421–428.

Woodchucks, *Marmota monax*, were studied in 1981 at six interchanges along Highway 417 in Ottawa and Nepean, Ontario, to determine population densities and how the animals utilize this man-made habitat. The fall density of 5.36 Woodchucks per hectare of a suburban interchange exceeded any density previously reported for this species in any habitat. Neither the areas nor the lengths of the home ranges of Woodchucks inhabiting the suburban interchange (Richmond) and one of the urban interchanges (Pinecrest) were significantly different. Watercourses, the expressway, and associated slopes encouraged linear shapes of home ranges. Woodchucks living on flat areas and those living adjacent to ramps that they crossed exhibited non-linear home ranges. These "road-wise" Woodchucks crossed single-lane on- and off-ramps frequently and successfully; wider roads were crossed infrequently.

Key Words: *Marmota monax*, Woodchucks, density, home range, expressway, interchange, parcel, ramp, rural, suburban, urban, movement-tracks, minimum area method, home range length, habitat utilization.

The literature dealing with population density and habitat utilization by Woodchucks, *Marmota monax*, (Hamilton 1934; Moss 1940; Grizzell 1955; de Vos and Gillespie 1960; Snyder et al. 1961; Bronson 1962; Merriam 1966, 1971; Doucet et al. 1974; Henderson and Gilbert 1978) has concentrated on free-living rural populations. The Queensway essentially bisects the city of Ottawa and urban parts of adjacent municipalities as it passes through rural, suburban, and urban areas. The rights-of-way of this expressway, especially its interchanges with cross-roads, provide habitats that are being exploited successfully to varying degrees by Woodchucks. Censusing was carried out in the spring and fall of 1981. By plotting the movement patterns of individual Woodchucks, the influences of this habitat on utilization by Woodchucks was determined.

Study Area

The four- to six-lane Queensway, part of Ontario Highway 417, runs in an essentially east-west direction through the cities of Gloucester, Ottawa and Nepean. Field work was concentrated at the six interchanges from Nepean, in the west to west-central Ottawa. Human development, including fences, sound barriers, and roads served to delineate the study areas at interchanges. Rural areas were predominantly surrounded by farmland. The suburban interchange had undeveloped field to the southwest while the remaining periphery of three quadrants was developed and urban in nature. Urban interchanges were surrounded by developed land, including houses or commercial buildings. The roadside right-of-ways on either side of the expressway were the only undeveloped areas where movement was likely to occur between interchanges in the study area. The Moodie Drive (45° 20′ N; 75° 50′ W); and Acres Road (45° 20′ N; 75° 48′ W) interchanges were in rural areas; that at Richmond Road (45° 20′ N; 75° 48′ W) was suburban; and those at Pinecrest Road (45° 20′ N; 75° 47′ W), Woodroffe Avenue (45° 21′ N; 75° 46′ W), and Maitland Avenue (45° 22′ N; 75° 45′ W) were in urban areas.

Each interchange consisted of grassy and/or shrubby areas divided by major roads and on- or off-ramps into "parcels," which are defined here simply as vegetated areas enclosed by roads. The areas of the 29 parcels studied ranged from 0.29 to 2.05 ha. *Inner* parcels were enclosed by on- or off-ramps, an interchange road, and the Queensway (e.g., Figure 1). *Outer* parcels were grassed areas peripheral to inner parcels that were enclosed by roads. Each parcel is identified by its interchange road name, compass orientation, and either no numeral for an inner parcel, or "2" for an outer parcel. On- and off-ramps are similarly coded, with a SW2 ramp being the outer ramp on the southwest quadrant of an interchange (e.g., Figure 2).

All parcels had roadside slopes. The steepest slopes on the inner parcels were adjacent to the interchange roads. These slopes at Pinecrest, Woodroffe, and Maitland were covered with deciduous shrubs or small conifers. A ditch surrounded the rounded portion of each teardrop-shaped inner parcel, providing slopes that rose to the central plateau ("flat area"), which comprised

most of the total parcel area. Interchange-road, ditch, and creek slopes rose at angles of about 30-60° from the horizontal plane.

Methods and Materials

A "burrow system" or "burrow" is defined as "the entrances and tunnels regularly used together by an individual" (Merriam 1971). Any single entrance of a burrow system is herein referred to as a burrow entrance. Grid stakes and/or landmarks were used to provide reference points for plotting the distribution of burrow entrances and Woodchuck movements on similarly marked 1:1250 maps.

Woodchucks were live-trapped at burrow entrances in National live-traps, using as bait slices of MacIntosh apples, and peanut butter mixed with rolled oats. Trapped Woodchucks were handled in a Halvorson cone (Halvorson 1972) redesigned for Woodchucks (Woodward 1982). A black Nyanzol fur-dye prepared as described by Melchoir and Iwen (1965) was applied to uniquely mark the fur of Woodchucks. The dye remained clearly visible on the underfur for the duration of the season on post-moult individuals. Each captured Woodchuck was permanently marked with two identically numbered No. 3 monel eartags (National Band & Tag Co., Newport, Kentucky). Marked Woodchucks are referred to by their eartage number or "name", sex, and age-class (Ad = adult and j = juvenile).

Censusing of Woodchucks was done in the spring (early April to mid-May) and fall (mid-August to mid-September) of 1981. The marked and unmarked individuals present on each parcel were counted. Unmarked and unidentified tagged Woodchucks were carefully observed for subtle natural markings to avoid counting them more than once.

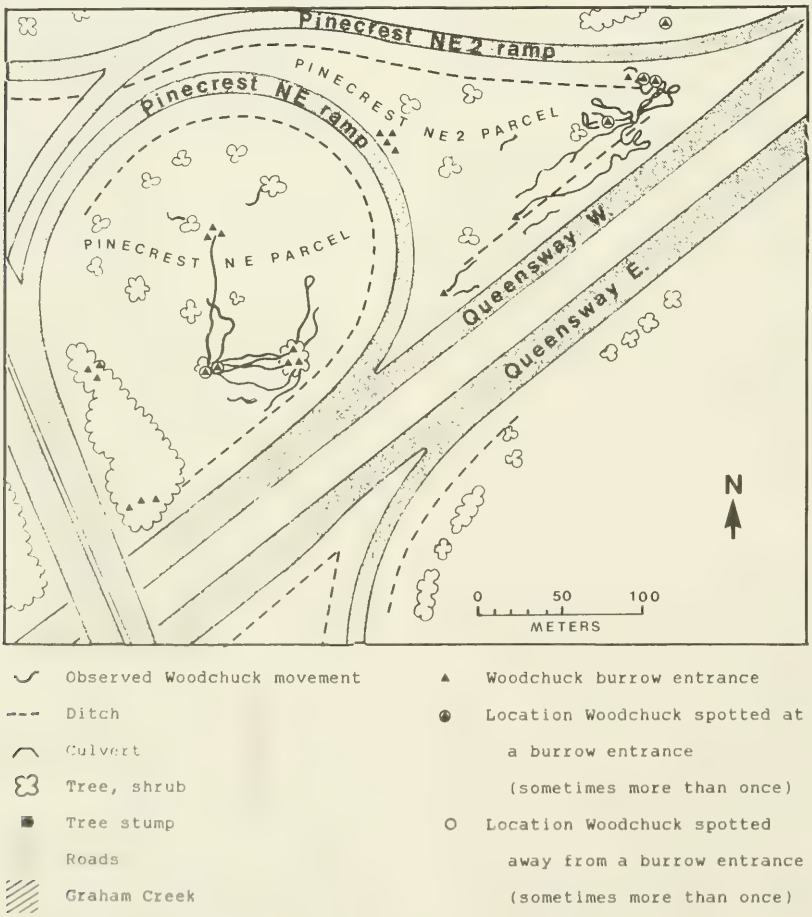

FIGURE 1. Range of #58♂j (Pinecrest NE & NE2: Observed 8.62 h; 11 spottings).

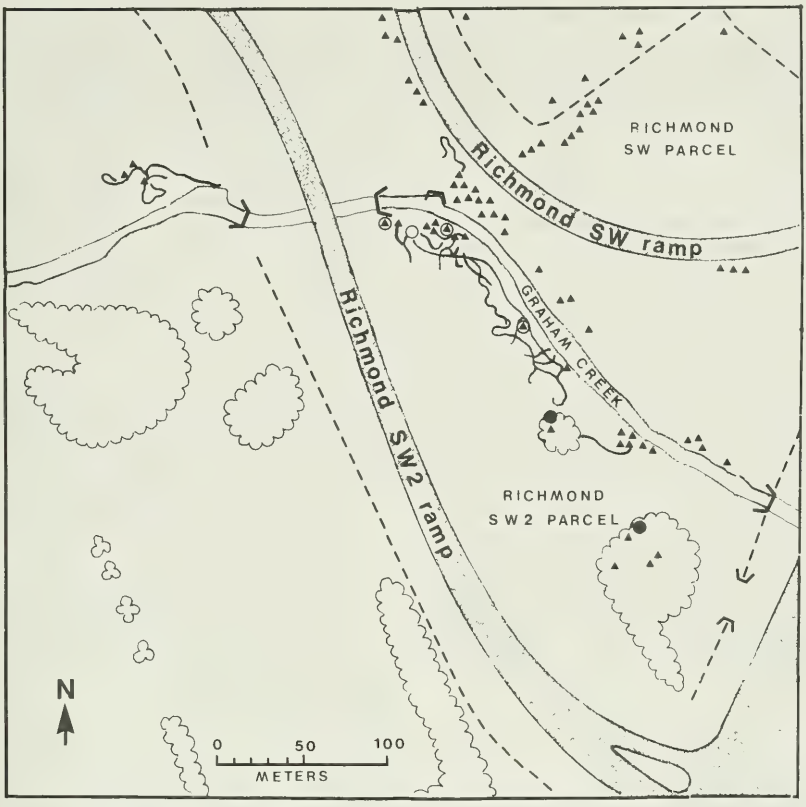

FIGURE 2. Range of #10♀Ad (Richmond SW2: Observed 8.30 h; 4 spottings). See Figure 1 for explanation of symbols.

Marked Woodchucks were observed primarily at Pinecrest and Richmond for 5- to 160-min periods and/or "spotted" at single point locations during the afternoon and early evening. The Woodchucks used in the home range comparison analyses were observed an average of 3.83 h with an average of five separate spottings. These observations were made over an average of 12 separate days per individual for a total of 117 h observation time and 129 spottings.

To conform with ecological tradition, and thus permit comparisons with the existing literature, movement data are presented as home range sizes expressed as minimum home range areas. Data sufficient for statistical analysis were obtained only for the Woodchucks of the Richmond and Pinecrest interchanges because of sparse populations at the other interchanges.

Movements were quantified in two ways. The area of the home range, containing all locations at which a marked Woodchuck was observed over the season, was estimated using the minimum area method (Godfrey 1954). The area of a polygon formed by joining the outlying points (avoiding concave lines) at which an individual was observed was measured. "Range length", the straight-line distance between the two most distant observed locations of a Woodchuck, was also calculated because Godfrey (1954) found this value reached its maximum with fewer observed locations than did home range area. The data for home range area and home range length comparison included only those Woodchucks from Pinecrest and Richmond that had been observed on more than three separate occasions (a total of twenty-four individuals).

To determine whether there were significant differences between male and female adults' and juveniles' home range sizes a Student-Newman-Kuels multiple range test for unequal sample sizes (Sokal and Rohlf 1969) was performed on both the home range area and home range length data. Because no significant differences existed between ranks for either method of quantifying home range size, the sex and age class data were pooled for each interchange.

An F-max test (Lehner 1979) showed that the Richmond and Pinecrest samples' home range area

variances ($F = 38.03$) and length variances ($F = 6.36$) significantly differed ($p < 0.05$). The Welch's non-parametric approximate t-solution (Scheffé 1970) (t*) was then used to determine whether the Richmond and Pinecrest Woodchucks exhibited significantly different areas or lengths of home range.

"Home range width" was measured as the distance between the two furthest points of the minimum area polygon at right angles to the home range length axis. Eighteen of the 56 individuals marked in my study area had sufficient data for home range length: home range width ratio analysis. A further eight individuals were naturally distinguishable due to pelage peculiarities. A second home range length and width were calculated for two of the Woodchucks to remove the effect of obvious sallies and/or areas used for a short period of time prior to or after an individual relocated. A Woodchuck's home range with a home range length: home range width ratio of more than 2.0 is considered to be "linear".

Road-crossing data were obtained from 35 marked Woodchucks at the six study interchanges. I assume the road-crossing data are representative of the interchange Woodchuck populations studies.

Results

Relative numbers and densities

The densities of burrow entrances in the study area are shown in Table 1. Assuming that there is some direct relation between the number of burrow entrances and the number of Woodchucks inhabiting an area, the Moodie, Acres, and Richmond interchanges were expected to have relatively high populations of Woodchucks. The three urban interchanges at Pinecrest, Woodroffe, and Maitland are comparable in having low burrow-entrance densities compared with those of the suburban and two rural interchanges. The low densities of burrow entrances at these urban interchanges suggest that their Woodchuck populations are low.

Fifty-six Woodchucks were live-trapped and tagged in the study area. Ten additional Woodchucks were individually distinguishable by natural markings. Fewer than 15% of the known resident Woodchucks eluded live-traps; most of these were juveniles.

Table 1 shows the densities of Woodchuck populations at the six study interchanges in the spring and fall of 1981. The relative densities of Woodchucks at the six interchanges were not proportional to the relevant density of burrow entrances counted in the fall. Acres and Richmond both had relatively dense populations of Woodchucks, as predicted, but Moodie had a low density. On the other hand, Pinecrest had a higher density than expected. Although high density of burrow entrances suggested that Richmond had the largest population of Woodchucks, the magnitude of its population's supremacy over other parts of the study area was unexpected.

Home range area

The Welch's approximate t-solution (Scheffé 1970) was used to determine if the home ranges of the 17 Richmond Woodchucks (Minimum home range area $\bar{X} = 0.34 \pm 0.22$ ha; Home range length $\bar{X} = 129.5 \pm 50.9$ m) and the seven Pinecrest Woodchucks (Minimum home range area $\bar{X} = 1.38 \pm 1.33$ ha; Home range length $\bar{X} = 217.8 \pm 128.3$ m) were significantly different. A difference would indicate that the two populations were different and/or they were utilizing their habitats differently. The mean Pinecrest home range area ($t^* = 2.05$, $p > 0.05$, 6 df) and home range length ($t^* = 1.76$, $p > 0.05$, 7 df) were not significantly greater than those of the Richmond sample.

Home range shape

No Woodchuck remained at one burrow system throughout the season (e.g., Figures 1, 2); rotation among three to 12 burrow systems was observed throughout the summer (Woodward 1982). These rotations usually occurred frequently. Less commonly, movements to different burrows were

TABLE 1. Woodchuck burrow entrance and population densities in the spring and fall of 1981.

		Density			
		Burrow entrances/ha		Woodchucks/ha	
Interchange	Setting	Spring	Fall	Spring	Fall
Moodie	Rural	1.8	1.9	0.38	0.57
Acres	"	2.6	3.1	1.13	1.69
Richmond	Suburban	3.4	4.4	3.85	5.36
Pinecrest	Urban	0.5	0.9	0.89	1.01
Woodroffe	"	0.6	0.7	0.16	0.49
Maitland	"	0.7	0.8	0.67	0.00

TABLE 2. Habitat factors and observed home range length: home range width ratios.

Contributing factor	Suburban $\bar{X}$	Suburban N	Suburban SD	Urban $\bar{X}$	Urban N	Urban SD
A. Queensway	4.7	9	2.1	4.0	4	1.4
B. Queensway/Flat area	—	—	—	3.6	1	—
C. Graham Creek	3.6	2	0.6	—		—
D. Graham Creek/Ramp	1.8	2	0.6	—		—
E. Shrubs	—		—	4.8	2	1.0
F. Ramp	2.2	3	0.2	—		—
G. Flat area	—		—	1.4	4	0.2
H. Woodchucks wandered	—	2	—	—	3	—

part of a dispersal event or were exploratory in nature (where an individual was seen only once at a particular burrow system). Six individuals wandered so extensively that no obvious association of home ranges with habitat topography was apparent (Table 2, B and H).

The three Pinecrest Woodchucks and the one Maitland Woodchuck living on flat areas exhibited non-linear home ranges (Table 2, G). One other Woodchuck (#49 ♀ Ad) initially utilized the flat area of Woodroffe NW2 but relocated to Woodroffe NW in late June and resided in the shrubby area of this parcel for the remainder of the season. Her linear movements (essentially perpendicular to the Queensway) were probably reinforced by the shrub-grass interface for there were no other Woodchucks inhabiting this parcel (Table 2, E).

This minimum-area polygons of the Woodchucks (three at Richmond and one at Acres) associated with ramp-areas exclusively, or of the two associated with Graham Creek (at Richmond SW2) that had crossed ramps to relocate sometimes had home range length: width ratios of less than 2.0 (Table 2, F and D). Movements were generally associated with the roadside slopes and the necessary inclusion of the ramp in the home range polygon obscured the internal linearity of the movement-tracks.

The Richmond SW2 Woodchucks residing adjacent to Graham Creek made almost all of their interburrow movements along the slopes where burrow systems were present (e.g., Figure 2). Grazing took place on the flat areas of the parcel, with movement usually not radiating more than 30 m from the burrow system in use. Somewhat barbell-shaped habitat utilization patterns and/or linear home range shapes resulted. Thus the two individuals associated exclusvely with Graham Creek exhibited linear home ranges (Table 2, C).

No study Woodchucks were seen either wet or swimming in Graham Creek at Richmond SW2, although wet ditches were readily traversed at Moodie SW and Richmond SW. Animals using both banks of Graham Creek travelled over the cement culverts on the east and west sides of the parcel, circumventing this water-barrier by using Man-made structures (see Figure 2).

The movements of Woodchucks along the slopes and flat area were essentially parallel to the Queensway (e.g., Figure 1). Ramps were crossed freely. Because movements around the burrow system in use rarely exceeded about 30 m, linear home ranges shapes resulted. This noise-vehicle

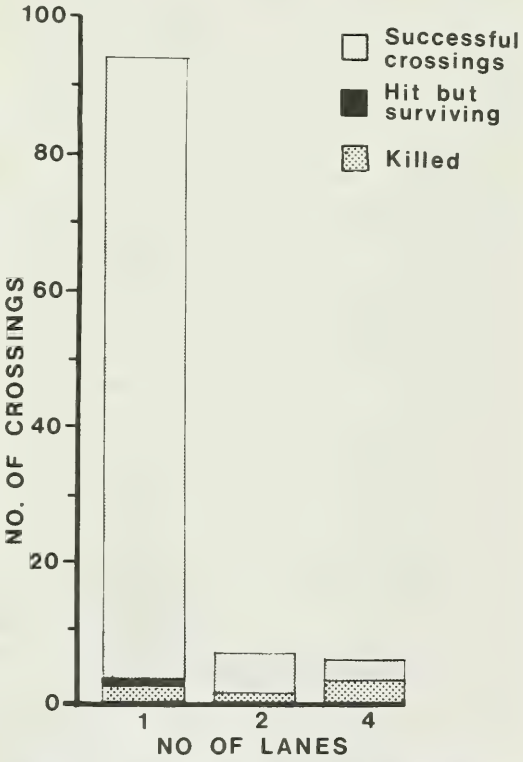

FIGURE 3. Successful and unsuccessful road crossings observed or implied (by locations of marked Woodchucks).

TABLE 3. Woodchuck densities reported in various habitats.

Density (Woodchucks/ha)	Habitat	Locality	Reference
0.01	Roadside adjacent to agricultural land	New York	Manville (1966)
0.02	Old-field associations	Pennsylvania	Bronson (1962)
0.05	Recessional moraine, marginal agriculture	Ontario (southern)	de Vos and Gillespie (1960)
0.07	Old-field associations and hedgerows	Maryland	Grizzell (1955)
0.18	Overpass embankments	Ontario and Quebec	Doucet et al. (1974)
0.34	Old-field associations	Pennsylvania	Snyder et al. (1961)
0.34	Urban park	Ontario (Ottawa)	Geggie (1980)
1.00	Occasionally grazed fields	Quebec	Geggie (1980)
3.33	University vegetable garden	Ontario (Ottawa)	Geggie (1980)

barrier could account for the home range linearity of 14 observed individuals for the long axes of their home ranges ran virtually parallel to the Queensway (Table 2, A and B).

Woodchucks commonly and extensively moved between interchange parcels (e.g., Figure 1). The observed animals freely crossed one-lane ramps (Figure 3). All but four of the 18 Woodchucks observed at Richmond and two of the 10 at Pinecrest crossed a ramp at least once during observed movements. Ninety-eight percent of the single-lane crossings were successful. Two study Woodchucks attempted to cross the two-lane Richmond NE2 ramp; one succeeded on six occasions (Figure 3).

Crossings of the four-lane Queensway or interchange roads is dangerous for Woodchucks. As Manville (1966) found with roadside Woodchucks, my study animals usually appeared unconcerned about passing vehicles. However, the honking of horns and the loud noises made by trucks driving over pavement irregularities invariably sent Woodchucks running to their burrows. The Queensway traffic volume (40 000-50 000 vehicles/day) and speed (maximum speed limit 100 km/h) were much higher than those on associated ramps (200-6650 vehicles/day, and 40-50 km/h, respectively). Only three study Woodchucks are known to have attempted to traverse the expressway; only one succeeded. One Woodchuck was killed during its attempt to cross Acres Road's four lanes, yet another successfully crossed Moodie Drive on two separate occasions. Thus three of six crossing attempts of four-lane roads were successful (Figure 3).

Discussion

The Queensway interchange Woodchuck densities (Table 1) are generally higher than those of mostly rural populations found in a variety of habitats (Table 3). Only the fall density at Maitland did not exceed that reported by Doucet et al. (1974) along Quebec-Ontario highway overpass embankments (0.18/ha). Most densities exceeded that of Snyder et al. (1961) for Woodchucks living in an old-field habitat (0.34/ha). The high density of a Woodchuck population (3.33/ha) reported by J. Geggie (1980. Effects of urbanization and population density on the behaviour of the Woodchuck (*Marmota monax*). Biology 4202 and 4203 Project, University of Ottawa, Ottawa, Ontario) illustrates the attraction of Woodchucks to vegetable gardens. However, the spring and fall population densities (3.85 and 5.36 Woodchucks/ha, respectively) at the Richmond interchange exceed this 'optimal' habitat density, and are the highest ever reported for this species in any habitat.

Although not quantified or proven a number of factors seem collectively to encourage the high densities observed at the suburban interchange. These include, (1) replacement by reproduction and immigration, (2) a lack of predators (domestic and endemic), (3) successful road-crossing behaviour, (4) a lush, grassy habitat with high Common Dandelion (*Taraxacum officinale*) growth and clear visibility, both due to regular mowing, and (5) ample drainage of burrows provided by slopes and drainage ditches surrounding the inhabited grassed areas.

When undertaking this study I expected the Woodchuck's movements to conform to the traditional concept of home range (Burt 1943). Although I observed some animals over a number of months, no long-term "established homes" were evident, and what Burt (1943) termed "occasional sallies" from the home range often were difficult to identify.

Home range areas reported in the literature range from 0.3-4.0 ha (Twitchell 1939; Bronson

1963; Merriam 1971; Hayes 1977). The home range areas of Richmond interchange Woodchucks ($\bar{X}$ = 0.34 ha) compared with the minimum of these values from rural areas. The Pinecrest Woodchucks' mean home range of 1.26 ha approaches the upper part of the range of the published home range areas. Although the two largest home ranges were observed at Pinecrest (3.99 and 2.38 ha for Mel2 ♀ j and #15 ♀ Ad, respectively), collectively the home ranges at Pinecrest were not significantly larger than those of Richmond individuals. The non-significance of this difference was unexpected and was likely due to small sample sizes and unequal observation effort amongst the study Woodchucks.

The observed linearity of home range of the observed Woodchucks at expressway interchanges is striking. Stumpf and Mohr (1962) found that linear home ranges or territories are characteristic among many mammals and birds. They concluded that compact home ranges may attract predators and that "extreme linearity for any given species [was] an expression of unsuitability of physical and biotic conditions in the area in which an animal live[d]". Range linearity due to an unsuitable environment does not seem applicable to Queensway Woodchucks. The lack of predators and apparent suitability of the habitat seem to encourage high populations of Woodchucks.

Corridors of suitable habitat for animals living along roads can enforce linearity of home ranges (Linsdale 1929; Stumpf and Mohr 1962). At the interchanges I studied the Woodchucks are not faced with an extremely narrow habitat corridor along the Queensway. The Queensway appears to function much as a watercourse where animal movements parallel the dispersal barrier and its associated slopes. The single-lane ramps do not act as dispersal barriers and are crossed with a high success rate by these "road-wise" Woodchucks.

The linearity of home ranges of the Richmond SW2 Woodchucks residing adjacent to Graham Creek is consistent with earlier findings that animals associated with watercourses often exhibit linear home ranges (Linsdale 1929; Stumpf and Mohr 1962; Sanderson 1966).

The topography of the interchange parcels moulds the movements and resulting home range-shapes of Woodchucks. Behavioural adaptation to this semi-enclosed Man-made environment illustrates the flexibility of Woodchucks that permits this species to cope successfully with the increasing number of land-use and technological changes being made by Man in and near urban environments.

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Spring Emergence and Male Chorus Behaviour in Fowler's Toads, *Bufo woodhousii fowleri*, at Long Point, Ontario

GENEVIEVE LAURIN and DAVID M. GREEN

Redpath Museum, McGill University, 859 Sherbrooke Street W., Montreal, Quebec H3A 2K6

Laurin, Genevieve, and David M. Green. 1990. Spring emergence and male chorus behaviour in Fowler's Toads, *Bufo woodhousii fowleri*, at Long Point, Ontario. Canadian Field-Naturalist 104(3): 429–434.

In 1988, emergence of Fowler's Toads (*Bufo woodhousii fowleri*) at Long Point, Ontario coincided with heavy thunder showers. The breeding population was small; only 14 male *B. W. fowleri* were observed and tagged over a two-week breeding season. Male Fowler's Toads tended to alternate their calls with those of close neighbors and call from stationary positions, either in small groups or individually. Active searching behaviour was not observed. Individual males exhibited strong calling site fidelity over successive nights. Calling rate and body temperature were significantly correlated. The Fowler's Toads emerged relatively late compared to previous years and there was only a short period of overlapping breeding seasons with sympatric American Toads, *B. americanus*. The two species of toads maintained separate choruses.

En 1988, l'émergence printanière des Crapauds de Fowler (*Bufo woodhousii fowleri*) à Long Point, Ontario a coïncidé avec un important orage. La population reproductive était peu abondante, 14 mâles *B. w. fowleri* seulement ont été observés et marqués dans une saison de reproduction de deux semaines. Les Crapauds de Fowler mâles tendaient à alterner leurs appels avec ceux de voisins rapprochés et appellent à partir de positions stationnaires, soit en petits groupes ou individuellement. Aucun comportement de recherche active n'a pas été observé. Les mâles démontraient une grande fidélité individuelle à leur site d'appel d'une nuit à l'autre. La fréquence des appels et la température corporelle démontraient une corrélation significative. L'emergence des Crapauds de Fowler étaient relativement tardive en comparaison aux années précédentes et il y eut seulement une courte période d'enjambement des saisons de reproduction avec les Crapauds américains (*B. americanus*) sympatriques. Les deux espèces de crapauds maintiennent des choeurs séparés.

Key Words: Fowler's Toad, *Bufo woodhousii fowleri*, spring emergence, breeding behaviour, Long Point, Ontario.

Green (1981, 1982) observed a non-random distribution of calling male toads at Long Point, Ontario, a narrow, sandy peninsula extending about 35 km eastward into Lake Erie. Fowler's Toad (*Bufo w. fowleri*) and the American Toad (*B. americanus*), called in small groups of conspecifics, and the occasional hybrids were usually found between such groups. This distribution may affect mating success of the hybrids if female choice is operative, as in *B. w. woodhousii* (Sullivan 1983a, Sullivan and Leek 1987).

B. w. fowleri hybridizes with sympatric *B. americanus* at many localities (Blair 1941; Zweifel 1968; Jones 1973) including Long Point (Green 1982, 1984) to produce fertile offspring (Blair 1941; Volpe 1952). Green (1984) showed that introgression between the two species at Long Point was minimal despite the presence of fertile hybrids. Some behavioural pre-mating isolating mechanism likely restricts hybrid mating success.

American Toads generally emerge and complete their breeding season earlier in spring than do Fowler's Toads. Irregular observations from 1978 to 1985 indicated that *B. w. fowleri* at Long Point started breeding activity around the beginning of May and continued for about a month (Green 1989). Because spring warming at Long Point proceeds from west to east, emergence of toads is about two weeks later at the tip than at the base of the point. Breden (1982, 1988) found emergence dates of Fowler's Toads in northern Indiana to range from 4 May to 11 May and calling activity to occur at air temperatures of 10°C and higher, although full choruses were not observed under 16°C. More southerly populations of Fowler's Toad begin breeding earlier. In Connecticut, the toads breed for about three weeks beginning in late April (Grogan and Bystrak 1973; Clarke 1974).

Only crude estimates of population size at Long Point (Green 1985, 1989) and anecdotal reports (Oldham 1988; Oldham and Sutherland 1986) have been available on spring emergence of the toads and the extent of their breeding activities there. In the spring of 1988, we monitored the entire Fowler's Toad breeding season at the western end of Long Point, documented climatic conditions during spring emergence and recorded the behaviour and distribution of breeding males in calling sites.

Methods

Nine breeding sites for toads at Long Point (Figure 1) were monitored from 2 May to 2 June 1988. Long Point is a narrow ridge projecting into

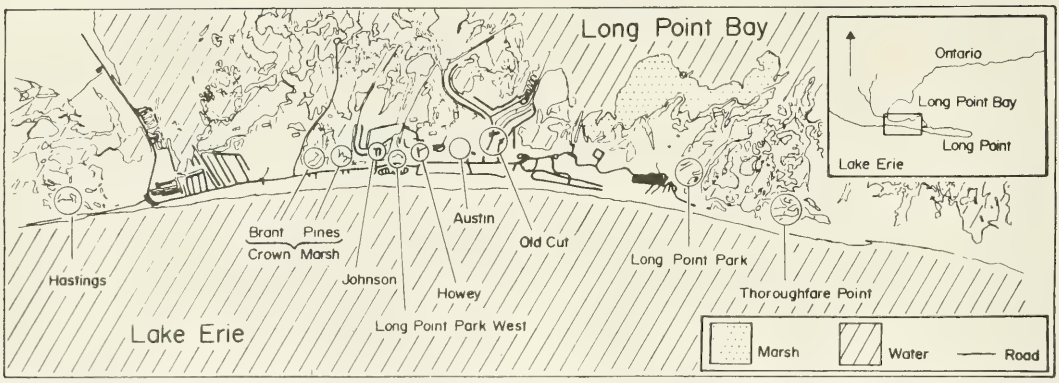

FIGURE 1. Map of the western base of Long Point, Ontario, indicating study sites mentioned in the text.

Lake Erie and encompassing Long Point Bay. Sand dunes and marshes that support *B. w. fowleri* are abundant. Human presence is restricted to private cottages near Long Point Park and camping sites within the Park from May to September. At all breeding sites, except Hastings (Figure 1), the water was continuous with Long Point Bay. Dominant marsh vegetation included cattails (*Typha*), sedges (*Scirpus*) and reedgrass (*Phragmites*). Vegetation was only emerging (3-5 cm) when we first arrived at Long Point on 2 May but by 2 June, dominant plants had grown at least 30 cm.

Each site was surveyed regularly for as long as toads were calling. If three consecutive nights passed without hearing any toads at a particular site, we concluded that breeding had ended there. This rule was flexible as periods of cold weather could temporarily stop all toad activity. Hastings Drive was surveyed only from 4-10 May but the other sites were checked nightly from 6 May to 2 June.

Individual toads were observed for periods of 10 min each (*see* Wells and Taigen 1984; Sullivan 1987). Toads were hand-captured, their cloacal temperatures were taken using a quick-reading thermometer (Miller & Weber Co.), and their snout-vent lengths (SVL) were measured to the nearest millimetre. All toads were toe-clipped for further identification (*see* Martof 1953). No more than two toes per foot were clipped in order to reduce possible risks of affecting survivorship (*see* Clarke 1972). Calling site characteristics (water depth and surface temperature, air temperature, vegetation, location, etc.) and the toad's behaviour, including calling rate (the number of calls per minute), movement, and calling attitude (percent of body exposed to air) were recorded. Nearest neighbour's identity and estimated distance (in feet) were also recorded.

As breeding activity declined in the study sites and toads had moved to their summer quarters along the beach (*see* Breden, 1982, 1988), we attempted a crude estimate of the *B. w. fowleri* population by surveying all toads active on 21 May along 1 km of beach at Thoroughfare Point (Figure 1). All toads except juveniles were sexed, measured and toe-clipped for future identification.

Results

Spring emergence: Fowler's Toads were not observed at Long Point until the evening of 15 May 1988. A rise in temperature (Figure 2) and a heavy thundershower with 14 mm of rain coincided with the discovery of an adult female and several immatures active on the roads. By 11:00 pm, after the brunt of the storm had passed, a few males could be heard calling in Crown Marsh. On later nights, Fowler's Toads were heard also at more easterly sites such as Long Point Park and Thoroughfare Point.

The Fowler's Toads' appearance was preceded by at least two weeks of activity of American Toads. Peak breeding activity of *B. americanus* at that site occurred from about 3 to 8 May, while they were most active in Crown Marsh from about 7 to 14 May. A few male American Toads lingered for an extra few days at each site after the peak of breeding activity had passed. The overlap in the breeding seasons of *B. americanus* and *B. w. fowleri* lasted four nights at Crown Marsh and one or two nights at Long Point Park West.

Fowler's Toads were only observed at air temperatures of 10°C or above and water temperatures of 13°C or above, similar to the observations of Breden (1988). The coldest body temperature recorded from a calling male was 13.5°C. Body temperatures of Fowler's Toads varied directly with air temperature and water temperature. Toads generally exhibited body

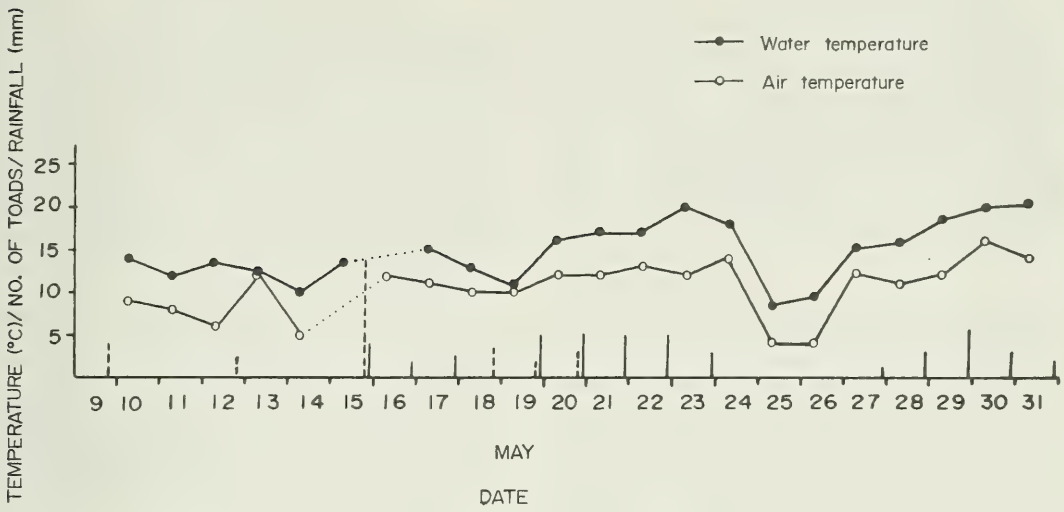

FIGURE 2. Fowler's Toad activity (number of calling males at all study sites), daily rainfall and air and water temperatures during the month of May 1988, at Long Point, Ontario. Black bars: number of calling male toads. Dashed bars: rainfall in millimeters.

temperatures between air and water temperatures, although some exhibited a body temperature lower than either air or water temperatures on the warmest nights (air temperature $> 20°C$) when evaporation from the skin might cool the animal below ambient temperatures. Evening water temperature was usually higher than air temperature (Figure 2).

We estimated the percentage of the body that was out of water for each calling toad but could find no correlation with air or water temperatures. About 80% of the time, a toad's body temperature was closer to water temperature than to air temperature, regardless of percentage of body out of water. Each toad observed calling had at least 40% of its body out of the water, as was observed by Aronson (1944) and Cory and Manion (1954).

Compared to previous years, the Fowler's Toad population seemed to be low. In 1980, for instance, Green (1981) collected 32 male Fowler's Toads and 2 females at the Crown Marsh in only two nights. During this study, in contrast, we never observed more than six individual males at the same site. No more than 14 calling males were recorded over the whole study site on any given night.

During a survey of foraging activity, 31 May, we found sixty toads (juveniles of both sexes and mature females) along the Lake Erie beach at Thoroughfare Point over a distance of about one km. Snout-vent lengths of all captured Fowler's Toads, including individuals found at Thoroughfare Point, Long Point Park, Long Point Park West, Johnson Avenue, Pines Parkway and Brant Parkway (Figure 3), suggested two age-size classes. Mature males, identified by dark throats and vocalizations, ranged from 47 to 59 mm. Juvenile males and females (presumed to be yearlings), measured 37-57 mm, but the larger of this group (44-57 mm), in the same size range as the adult males can be presumed to be juvenile females. Adult females measured 68 to 74 mm.

Calling and breeding activity: Male Fowler's Toads called in groups of two to five toads. During the brief overlap in breeding season of American and Fowler's toads, *B. fowleri* were almost always seen closer to other Fowler's Toads than to calling American Toads. A Fowler's Toad calling on 20 May was close to a male American Toad but the latter neither called nor exhibited any other breeding behaviour.

Groups of marked Fowler's Toads were quite cohesive. The same individuals maintained the same general relationships to each other on successive nights. At Brant Parkway, toads coded 1, 2 and 3 were usually in close proximity while numbers 101 and 104 were farther removed (Table 1; Figure 4). At Long Point Park West, toads coded 6 and 8 were always observed at the same relative distance from each other and returned to the same calling sites for all but one night. Toad coded 9 was at the same spot (within 30 ft) at Johnson Avenue for all three nights it was monitored. In contrast with Clarke's (1974) findings, we found that individuals were often active for more than two nights in a row. Three toads called for five consecutive nights until they were interrupted by cold temperatures and frost.

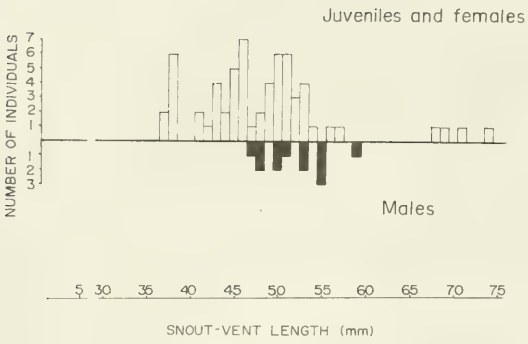

FIGURE 3. Snout-vent lengths of 84 juvenile and adult female Fowler's Toads (white bars) and adult male Fowler's Toads (black bars) captured and marked at Long Point, Ontario, in May 1988. Most of the females and juveniles were captured along a one kilometer stretch of beach at Thoroughfare Point on 23 May.

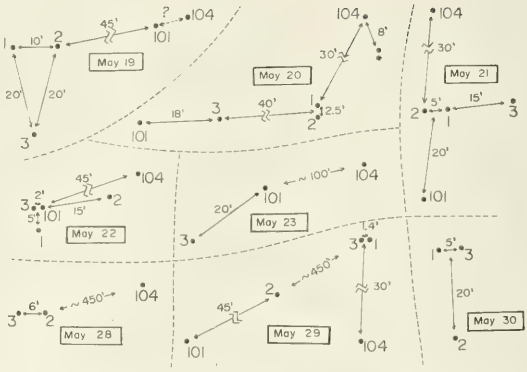

FIGURE 4. Maps of the respective calling sites of five individual male Fowler's Toads (indicated by field number as in Table 1) on active nights at Crown Marsh. Inter-individual distances estimates are indicated in feet.

Male Fowler's Toads usually alternated calling with each other, especially with close neighbors (less than 15 ft). When overlap in calls was observed, it was mostly on very active nights when calling frequency was highest (8-10 calls/min). Within a chorus, any given toad typically called 1 to 2 sec after the end of a neighbor's call.

In contrast with Sullivan's (1982) study of *B. w. woodhousii*, calling rate correlated positively with body temperature ($r = 0.499$, $p = 0.0006$; Figure 5). Toads with the highest recorded body temperatures (23.0°C and 23.2°C) exhibited the highest calling rate (8 to 10 calls/min) while toads with the lowest range of body temperatures (14 to 16°C) either called at a much slower rate (less than 4 calls/min) or were silent.

TABLE 1. Nearest neighbours of five individual male *Bufo w. fowleri* (indicated by field number) on active calling nights at Crown Marsh. Toads further than 15 feet away were not considered neighbours. Closest neighbour is indicated first. Neighbours at equal distance are in parentheses. A dash indicates no other toad within 15 ft.; abs = individual absent.

	Individual (field number)				
	1	2	3	101	104
Date:					
May 19	2	1	—	—	
20	2	1			
21	2,3	1	1	—	—
22	(3,101)	101	101,1	3,1	—
23	abs	abs		—	—
28	abs	3	2	abs	—
29	3	—	1	—	—
30	3	—	1	abs	abs

Discussion

There are many similarities between this northern population of *B. w. fowleri* at Long Point and that studied by Breden (1982; 1988) in northern Indiana. Clarke (1975) and Breden (1988) showed that females grow faster than males, are thus larger at an equivalent age, and reach a larger size. This accounts for the distribution of size classes among the toads we examined at Long Point. Breden (1988) found that only two age classes could be distinguished in Indiana: adults two years old or more and yearling juveniles. Although Breden (1988) reported a maximum size 62.2 mm for adult females and 58.8 mm for males, we found a greater size disparity between sexes, with some females exceeding 70 mm (Figure 3).

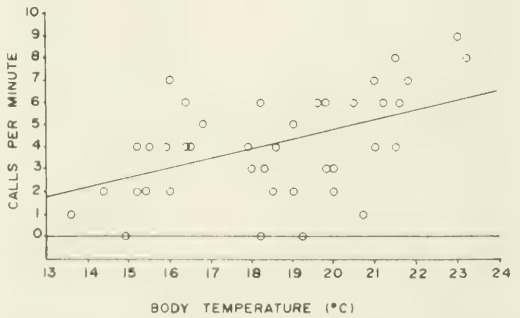

FIGURE 5. Calling rate (calls/minute) versus cloacal temperature for calling male Fowler's Toads over all active breeding nights at all sites at Long Point, Ontario. $y = 0.442x - 4.001$, $r^2 = 0.249$

In explosive-breeding anurans such as toads, males outnumber females at breeding sites and search actively for mates. At low densities, males of these species often space themselves regularly and call from stationary positions (Wells 1977). Fowler's Toads are explosive breeders and male density during our study was low. Our observations agreed with those of Wells (1977) and Arak (1983), who found active searching to be minimal and that individuals remain at stationary calling sites. Sullivan (1983b) found similar results in low-density breeding aggregations of *Bufo cognatus, Scaphiopus multiplicatus* and *S. bombifrons.*

Male Fowler's Toads tended both to gather in homospecific choruses and to show strong calling site fidelity. Breden (1987) found that 73% of Fowler's Toads bred for the first time in their natal pond. Clarke (1974) also reported fidelity of Fowler's Toads to calling sites.

Alternation of calls between neighbouring individuals, as in chorusing Fowler's Toads, has been reported other anurans, such as *Hyla regilla* (Awbrey 1978), various hylids (Duellman 1967), *Hyla crucifer* (Rosen and Lemon 1974) and *Bufo w. woodhousii* (Sullivan 1985). If time, rather than territory, were a limiting resource, neighbouring males should alternate their calls in order to fit them into available temporal "windows" between the calls of their neighbors. This would minimize acoustic interference and could provide females with a better opportunity for mate selection. This may be particularly important in explosive breeders (Wells 1977) that do not defend territories or resources (Arak 1983). The males that could not fit their calls into available temporal spaces could thus be forced to seek alternative strategies for mate acquisition such as active searching. This could account for the switch in strategy observed among breeding males as density changes (Wells 1977; Sullivan 1982).

There were very limited interspecific contacts between populations of *B. w. fowleri* and *B. americanus* at Long Point in 1988. No hybrids were found but it would be premature to conclude that the hybrid zone has disappeared. Fluctuating environmental factors may affect the extent of breeding season overlap and population density. Although Jones (1973) argued that hybridization at a sympatric *B. americanus*/*B. w. fowleri* site in Indiana had ceased due to reinforcement of isolating mechanisms, such conclusions seem premature (Loftus-Hills 1975; Green 1984). Hybrid zones require a more dynamic model of fluctuating hybrid frequency over time.

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Distribution and Grizzly Bear, *Ursus arctos*, Use of Yellow Sweetvetch, *Hedysarum sulphurescens*, in Northwestern Montana and Southeastern British Columbia

W. Daniel Edge[1,2], C. Les Marcum[1], and Sally L. Olson-Edge[1]

[1]School of Forestry, University of Montana, Missoula, Montana 59812
[2]Present address: Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon 97331

Edge, W. Daniel, C. Les Marcum, and Sally L. Olson-Edge. 1990. Distribution and Grizzly Bear, *Ursus arctos*, use of Yellow Sweetvetch, *Hedysarum sulphurescens*, in northwestern Montana and southeastern British Columbia. Canadian Field-Naturalist 104(3): 435–438.

Grizzly Bears (*Ursus arctos*) dug Yellow Sweetvetch (*Hedysarum sulphurescens*) at 59 of 199 plots sampled. Yellow Sweetvetch had a wide ecological amplitude, occurring in several community types within a broad range of elevations and aspects, and was associated with some form of disturbance in 94% of the plots. Percent ground cover of Yellow Sweetvetch was twice as high ($P < 0.001$) at dug versus undug sites. Sites dug by Grizzly Bears were primarily on sandy or rocky soils. We suggest that broadcast seeding Yellow Sweetvetch in areas such as clearcuts may enhance Grizzly Bear habitat, but sites should be selected tominimize human-bear encounters.

Key Words: British Columbia, Grizzly Bear, *Ursus arctos*, habitat, Montana, Yellow Sweetvetch, *Hedysarum sulphurescens*.

The root of Yellow Sweetvetch (*Hedysarum sulphurescens*) is an important food for Grizzly Bears (*Ursus arctos*) from northwestern Montana and adjacent Canada to Alaska and the Yukon (Murie 1944; Pearson 1975; Russell et al. 1979; Stelmock 1981; Holcroft and Herrero 1984; Hamer and Herrero 1987). Grizzly Bear use of timbered sites during early spring in the North Fork of the Flathead River drainage of Canada has been attributed to the presence of Yellow Sweetvetch and carrion (McLellan 1986). Mace and Jonkel (1986) reported extensive spring use of Yellow Sweetvetch in the Flathead drainage in Montana. Yellow Sweetvetch comprised 5%, 4% and 13% of the Grizzly and Black Bear (*Ursus americanus*) scats in Glacier National Park (GNP) during the spring, late summer and fall, respectively (Kendall 1986).

Yellow Sweetvetch is a robust legume, up to 8 dm high, with a large taproot. It is often abundant where found, but occurs in small irregularly-dispersed patches. The ecology of Yellow Sweetvetch has not been studied in the southern portion of its range, and its importance as a spring and fall Grizzly Bear food makes it a plant of interest to land managers. Jonkel and Hadden (1986) identified the ecological relationships of key Grizzly Bear foods as an important research need. The purpose of this study was to determine the ecological distribution of Yellow Sweetvetch in northwestern Montana and southeastern British Columbia, and determine the factors that distinguish sites where bears had dug the taproot from undug sites.

Study Area

This study was conducted in northwestern Montana and southeastern British Columbia, on both sides of the Continental Divide. Plots west of the Divide were located in the North Fork of the Flathead River drainage in GNP, and on the Flathead National Forest (FNF) from approximately Big Creek north to the international border. Plots in British Columbia were on Crown lands, also on both sides of the river within 15 km of the border.

Plots east of the Divide were located mostly in the foothills and lower slopes of the mountains from the Two Medicine area to the international border, in or near GNP, and to the south along the eastern front of the Rocky Mountains between Dupuyer Creek and the Teton River. A few plots were located along the Divide, above or near timberline in the vicinity of Logan Pass in GNP.

Lower elevations in the North Fork of the Flathead ranged from 1086 to 1434 m, while elevations east of the Divide ranged from 1110 to 2036 m. Mountains in the area were from 2400 m to over 3000 m in elevation.

The study area west of the Divide is primarily influenced by Pacific maritime weather (Kendall 1986) with cold, snowy winters and cool, moderately moist summers. In contrast, areas east of the Divide are influenced more by continental weather, and tend to be cooler and drier. These contrasts in climate, along with topographic effects, result in different plant communities on each side of the Divide. Vegetation on the west side is similar to that of the Pacific Coast, while

vegetation on the east side of the Divide resembles the flora of the plains and Rocky Mountains farther to the east and south (Lesica 1985).

All areas sampled were within the occupied range of the Grizzly Bear.

Methods

Yellow Sweetvetch is local in distribution; it occurred in 73 of 1482 plots sampled by Pfister et al. (1977). Because of this patchy distribution, a random or systematic sampling program would have required a much greater sampling intensity than our study allowed. Sample sites were located by talking to biologists, surveying from roads, or by walking trails within the study area. Our sampling program allowed us to make inferences concerning sites where Yellow Sweetvetch occurred, but not about sites where it did not occur. Once an area containing Yellow Sweetvetch was found, we placed a 5 × 10 m plot either to maximize the number of bear diggings or the density of Yellow Sweetvetch. We sampled more than one plot in the same area if aspect or plant community changed.

At each plot, aspect (degrees azimuth), slope (%), elevation (m), slope configuration, habitat type (Pfister et al. 1977), forest cover type, successional stage, and sources of disturbance (livestock, fire, flood, logging, wildlife, or other) were recorded. The overstory canopy coverage was estimated in 25% intervals. Canopy coverage for all understory vegetation was classified by species into the following categories: $\leq$ 1%, 1–5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, and $>$ 95%.

We used Chi-square tests to determine if sites where Grizzly Bears dug Yellow Sweetvetch were independent of the environmental factors at those sites. We used discriminant function analysis (DFA) to test the null hypothesis that factors at Yellow Sweetvetch sites dug by bears were not different from those at sites where bears did not dig.

Results

One hundred ninety-nine sites containing Yellow Sweetvetch were sampled between 1 June and 30 July, 1987. Bears dug Yellow Sweetvetch at 59 of these sites. We found Yellow Sweetvetch to have a broad ecological amplitude. It occurred on all aspects, at elevations ranging from 1086 m to 2036 m, and has been collected in the study area at elevations up to 2621 m (Bamberg and Major 1968). Slope steepness at Yellow Sweetvetch sites averaged 19.9% and ranged from 0 to 109%. It occurred on mesic sites characterized by riparian meadows, Cottonwood (*Populus trichocarpa*) communities, and spruce (*Picea* spp.)-Horsetail (*Equisetum arvense*) and Subalpine Fir (*Abies lasiocarpa*)-Bedstraw (*Galium triflorum*) habitat types (Pfister et al. 1977), as well as xeric sites such as the Limber Pine (*Pinus flexilus*)-Idaho Fescue (*Festuca idahoensis*) habitat type. Although the majority of sites were on sandy or rocky soils (66%), 14% and 20% of the sites were on loam and clay soils, respectively. Yellow Sweetvetch occurred at sites ranging from 0-75% overstory canopy coverage. However, closed canopies appeared to preclude Yellow Sweetvetch; only 2.5% of our plots were in stands with $>$ 50% canopy closure.

Yellow Sweetvetch was associated with some form of disturbance in 94% of the plots. Sources of disturbance were not mutually exclusive, and those most common were rodent diggings (42.7%), bear diggings (29.6%), livestock or native ungulate use (26.6%), flooding (16.1%), fire (11.1%) logging (11.1%), and road cuts (10.1%). Time since disturbance was estimated for 61 of the disturbed sites, and in 33% of these plots the disturbance occurred $\geq$ 25 years ago.

Sites where bears used Yellow Sweetvetch were different from unused sites. Using DFA on ordinal or ratio variables only (slope, Yellow Sweetvetch density, % Yellow Sweetvetch ground cover, % bare ground, and % total ground cover), used and unused sites were different ($F_{1,181} = 22.39$, $P < 0.001$) from one another. Percent ground cover of Yellow Sweetvetch was the only variable used in the discriminant model which correctly classified 72.9% of the cases; mean ground cover at used sites (11.3%) was almost twice that at unused sites (6.1%). Bear digging was not independent of overstory canopy coverage ($\chi^2 = 7.19$, $df = 2$, $P = 0.028$), with most digging (64.4%) occurring in stands with 1-25% overstory canopy coverage (Figure 1). Bear-use sites were not independent of soil type ($\chi^2 = 23.67$, $df = 3$, $P < 0.01$). Bears dug Sweetvetch predominantly on rocky and sandy soils (89.8%), while loam and clay soils received little use (10.2%) (Figure 2).

Discussion

Ease of digging appears to be the most important factor determining which Yellow Sweetvetch sites were used by Grizzly Bears. Our results indicated that easily excavated soils with abundant Yellow Sweetvetch are most likely to be used by Grizzly Bears. Holcroft and Herrero (1984) reported that ease of digging appeared to be more important than the abundance of Yellow Sweetvetch in determining what sites were dug by Grizzly Bears; gravelly and rocky sites on steep slopes were common characteristics of locations where bears dug Yellow Sweetvetch in their study area. Steepness of slope was not an important factor in our study probably because our method

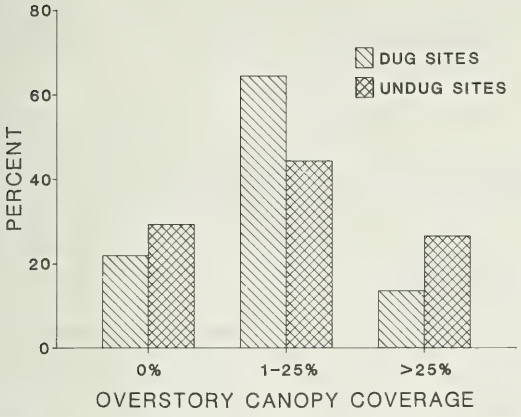

FIGURE 1. Percent of Yellow Sweetvetch plots with and without Grizzly Bear diggings with respect to overstory canopy coverage in northwestern Montana, Summer 1987.

of selecting plot sites was biased towards areas with more moderate slopes.

Bear use of Yellow Sweetvetch appeared to stimulate production of the plant (Holcroft and Herrero 1984; Jonkel and Hadden 1986). At virtually every site where Yellow Sweetvetch had been dug, new, robust plants were growing out of the excavated holes, and these sites appeared to have been used repeatedly by bears. Bears apparently remove only the upper part of the root, allowing the plant to resprout. In addition, the sites that had been dug by bears had numerous patches of upturned soil which were good seed-beds as evidenced by the large number of seedlings at these sites.

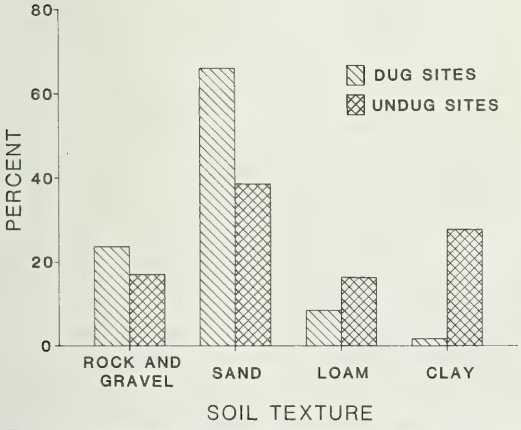

FIGURE 2. Percent of Yellow Sweetvetch plots with and without Grizzly Bear diggings with respect to soil type in northwestern Montana, Summer 1987.

Northern Sweetvetch (*H. boreale*), a closely related species, has been extensively studied (Redente 1980, 1982), and used for revegetation of disturbed lands (Plummer et al. 1968; Rumbaugh 1983). In addition, *H. coronarium* is used for forage production in Africa and Europe (Reed 1981), and *H. mongolicum* is used in China for forage, soil conservation and sand dune stabilization (Min and Hovin 1983). These species grow under a wide range of environmental conditions, and produce abundant, palatable forage for wildlife and livestock. The wide range of environmental conditions found for sites containing Yellow Sweetvetch in this study, the use by native and domestic ungulates (26.6% of plots), and the persistance of Yellow Sweetvetch on disturbed sites, indicate that the species is palatable, and well suited for revegetation.

Broadcast seeding of Yellow Sweetvetch on disturbed sites, especially logging units, could enhance Grizzly Bear and big game habitat in northwestern Montana. Grizzly Bears are most likely to use sites that are steep and have a high component of sand or rock in the soil. Yellow Sweetvetch should not be planted at sites near open roads or trials in order to minimize the potential for bear-human encounters, and to reduce bear vulnerability to hunting.

Northern Sweetvetch has a hard seed coat that requires scarification to obtain adequate germination under laboratory conditions (Redente 1982). Germination of Yellow Sweetvetch in Montana was about 50% for fall plantings and 20% for spring plantings (M. C. Majerus, Soil Conservation Service, personal communication), indicating that stratification would enhance germination success. Experimental trials should be conducted to determine ideal conditions for site and seed preparation.

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Inland Flight Patterns of Marbled Murrelets, *Brachyramphus marmoratus*, on the Queen Charlotte Islands, British Columbia

A. E. Eisenhawer and T. E. Reimchen[1]

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9
[1]Present address: Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2

Eisenhawer, A. E., and T. E. Reimchen. 1990. Inland flight patterns of Marbled Murrelets, *Brachyramphus marmoratus*, on the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 104(3): 439-444.

Numerous published field accounts indicate that Marbled Murrelets (*Brachyramphus marmoratus*) leave the ocean at dusk and fly to unknown destinations inland during the breeding season. We describe here characteristics of the frequent flight activity of murrelets observed at Coates Lake, 6 km from the west coast of the Queen Charlotte Islands, British Columbia. Most flights between the lake and the ocean occurred within 30 minutes of sunrise and sunset. Bidirectional flights occurred during both periods. Morning flights were often circular over the lake and included frequent vocalizations while evening flights trended to be unidirectional and silent. We observed repeated use of characteristic flight paths through the old growth forest around the lake during particular time periods (± 5 minutes) on successive nights. Some of these flight paths terminated at particular trees; we observed single birds or pairs of murrelets in trees on fifteen occasions. One of these is interpreted as a mating event while others appear to represent feeding flights from the ocean to presumed prefledglings in the trees. Since nesting sites of this species are largely unknown, our observations suggest that the high fidelity of flight paths can be exploited to locate potential nesting trees.

Key Words: Marbled Murrelet, *Brachyramphus marmoratus,* inland flight, nesting areas, Queen Charlotte Islands, old growth forest, reproductive behaviour.

Marbled Murrelets (*Brachyramphus marmoratus*), one of the common alcids in Pacific coastal waters, are exceptional among alcids in nesting solitarily, often at considerable distances from the ocean and in a diversity of habitats (Drent and Guiguet 1961; Day et al. 1983). Despite decades of field surveys, only 12 nests have been found (Sealy 1974a; Carter and Sealy 1986) and these are geographically distant. Adult birds are common in nearshore oceanic waters during summer and are regularly observed flying inland during the breeding season (Summers 1974; Sealy 1974b). However, since these flights occur at the onset of darkness, specific nesting areas or general destinations inland have not been determined.

During a five-year survey of aquatic birds at Drizzle Lake (Reimchen and Douglas 1984a), in the north-eastern Queen Charlotte Islands, several Marbled Murrelets were occasionally observed during summer and were suspected of nesting in adjacent forests. Unlike observations within the forests, lakes provided a large open area of high visibility where flight patterns could be observed and vocalizations heard. As such, during ichthyological surveys of lakes throughout the Queen Charlotte Islands (Reimchen, unpublished data), general observations of murrelet activity were made (Reimchen 1991). Three lakes with relatively high murrelet flight activity were discovered, of which one was chosen for systematic observation. We describe here the frequency, direction and daily pattern of flight activity. Our results suggest that nest sites can potentially be located with these methods.

Methods

Preliminary observations on flight activities of Marbled Murrelets at Coates Lake (53°40′N, 132°51′W), were made June 1982 (by TER) while extended observations were made daily from 1 June to 3 August, 1986 (by AEE). This lake (elevation 35 m) is 2.2 km long and lies approximately 6 km up a forested valley from the west coast of Graham Island, the largest island in the Queen Charlotte Group. The surrounding old-growth forest is a mixture of Western Hemlock (*Tsuga heterophylla*), Sitka Spruce (*Picea sitchensis*), Western Red Cedar (*Thuja plicata*), and Yellow Cedar (*Chamaecyparis nootkatensis*). The canopy ranged from about 40 m to 70 m in height. Ground cover was predominantly moss (80-100%) over deadfall (10-30%). The valley was bordered to the north and south by ridges (to 700 m) with subalpine scrub forest of Lodgepole Pine (*Pinus contorta*) and cedars and some alpine vegetation.

An initial survey (2-5 June) of murrelet flight activity consisted of overnight surveillance from the lake shore and from three points along the north ridge. Subsequently, most observations were made from a gravel bar near the southeast corner of the lake and from an inflatable raft about 200 m

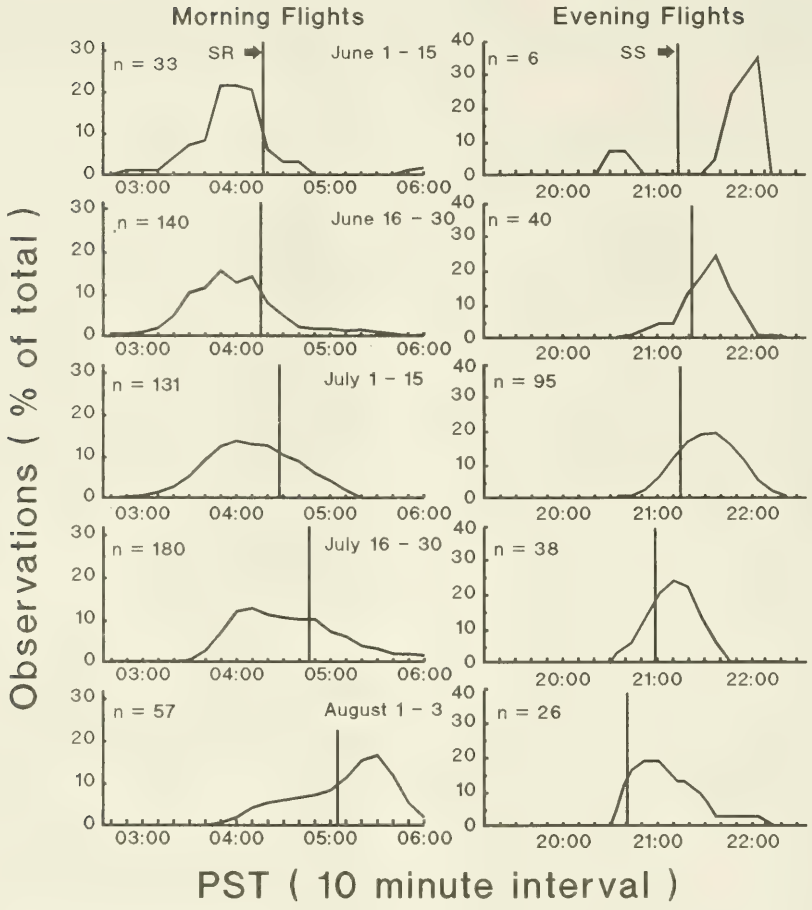

FIGURE 1. Dawn and dusk flight frequencies per ten minute period (PST), averaged over two week periods. Local astronomical sunrise (SR) and sunset (SS) are indicated. Numbers of observation days for biweekly time blocks are 7, 15, 6, 11 and 3 days respectively for dawn flights and 10, 15, 6, 12 and 3 days, respectively, for dusk flights.

from the shore. On about one-half of the nights, interspersed over the study period, flights were monitored at a number of locations in the surrounding forests. Activity was initially monitored continuously but observations periods were later reduced when it became apparent that most flight occurred near dawn and dusk. The characteristic whistling sound of murrelets' wingbeats and frequent vocalizations allowed detection of flight at darkness. For recording data, we considered a single "flight" as the full interval between when a murrelet was initially detected (visual or aural) until it could no longer be followed. During brighter periods before dusk and after dawn, we were able to note whether the flights were comprised of single birds or groups. Directional sources of weak vocalizations were determined with a parabolic microphone mounted on a rotating tripod. All times are given in Pacific Standard Time (PST).

Results

The survey of the ridge north of the lake yielded no evidence of murrelets in these high elevation habitats but calls were heard to come from the valley towards the lake. Observations on the lake shore immediately preceding and following the ridge survey showed extensive vocal and flight activity indicating that the lake and surrounding forests, rather than the ridges, were the active areas.

Flights occurred near dawn and dusk with no detectable activity during daylight (0700-2000 h) or "darkness" (2300-0230). Peak activity in the morning was about 30 minutes before sunrise throughout the observation period while most

evening flights occurred about 45 minutes after sunset in early June but thereafter occurred near sunset (Figure 1). Overall, dawn flights appeared to be more frequent than evening flights ($\bar{x} = 12.9/d$, range 1-50 vs $\bar{x} = 4.5/d$, range 0-22 respectively, $t = 3.57$, $P < 0.001$, $DF = 72$, unpaired t-test).

At dawn, the first flights (generally detected by vocalizations) originated from the forest adjacent to the lake. When visible, the birds flew in circular or other circuitous patterns over the lake and surrounding forest generally 100-200 m above the lake surface and treetops. These flights were comprised of single birds (N = 112), pairs (N = 26) and occasional small groups (3-5) (N = 4). Vocalizations were prevalent. Although flights were bidirectional, there appeared to be a net movement towards the ocean: the first flights detected were from the surrounding forests and the last flights from the direction of the sea.

In contrast, evening flights tended to to be unidirectional and silent. Inland (easterly) flights were more frequent than seaward (westerly) flights (68 versus 39 respectively) and generally occurred about 10 min earlier (Figure 2). Flights were predominantly singles (N = 85) and secondarily pairs (N = 6). Some flights followed consistent routes leading from the lake through particular gaps in shoreline trees to destinations in the forest. Some of these flight paths were "tracked" (by observations on successive nights) about 1 km up the south valley while two others were traced along a tributary creek to about 300 m up the valley. In one of these monitored from 19-30 July, not only was there fidelity of flight paths but these were consistent to within 2-5 minutes on successive evenings. Pairs of murrelets were occasionally seen flying into the forest on one of these routes yet occasionally, in 3-4 minutes, a single bird would return along the same flight path heading in the direction of the lake. That the second bird did not return, despite continuous observation for several hours, suggests that it remained in the forest during the night.

Marbled Murrelets were seen in large trees on fifteen distinct occasions and at seven localities. These were either trees on the lake shore or adjacent to openings in the forest canopy up to about 1 km from the lake. Most of these sightings involved brief visits in which the murrelets landed on higher branches, remained for up to five minutes and then departed. In one instance (13 June) during continuous observation at a tree, a single murrelet stayed overnight approximately two-thirds of the way up a Sitka Spruce on the lake shore and then departed at dawn. It was not seen on successive nights.

The most extensive observations of tree-associated activity were made at a large hemlock (est. 50 m tall, 1.2 m dbh) about 20 m from lake shore. On 8 June, beginning at 03:48, two murrelets repeatedly circled the tree in broad arcs and landed (14 times) on a branch about 35 m above the base of the tree and remained for 1 to 20 seconds. They were not visible when sitting on the branch. Seven of these landings were short duration (less than 5 seconds) and occurred when one of the murrelets appeared to fly onto the back of the leading bird as it landed. Although the birds were lost from sight during this brief interval, wing-flapping was heard on each occasion. Following these events, the birds flew over the lake

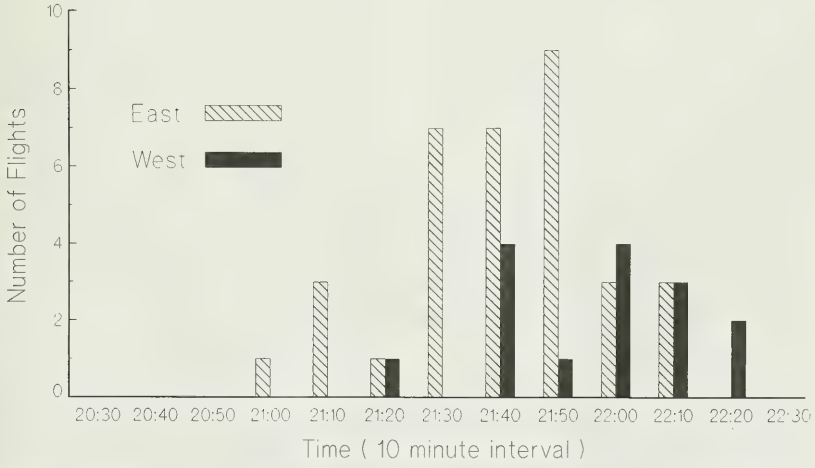

FIGURE 2. Evening flight directions per ten minute period (July only). Only visual sightings included.

and were lost from sight. On the following morning, at 03:50, two murrelets again flew to the tree, remaining on the branch for 16 minutes (no wing-flapping heard). This behaviour was repeated on the subsequent morning (10 July) during the same time period (03:52-04:07). No murrelets were observed in the vicinity of the tree on the next three nights and continuous observations at this tree were abandoned. Over the next week, the tree was monitored on five nights (7, 8, 9, 13, 14 July) but no activity was observed.

Observations of this tree were resumed on the evening of 31 July. At 21:11, a single murrelet landed on the tree, remained for three minutes, after which it departed and flew north across the lake and was lost from sight. On 1 August, at 20:56, a single murrelet attempted to land on the tree, but failed and flew over the lake. At 20:57, a murrelet, probably the same individual, approached from the lake and landed on the tree. In three minutes (21:00), a single call was heard from the tree and at 21:02, a second bird approached from the lake and landed on the tree. At 21:03, a single bird departed the tree and flew low over the lake. Over the next 17 minutes, a single call was heard from the lake. At 21:20, a second call was heard from the lake and within 2 seconds, the second murrelet departed from the tree. No more activity was observed at or near the tree that evening. On the following evening, at 21:06, a single bird, which appeared to be carrying a fish, flew to the same tree but failed to land and circled over the lake. Thirty seconds later, a murrelet (probably the same individual) landed on the branch. This branch was about 5 m higher than that used in early June. At 21:08, a second murrelet approached from the lake and landed on the branch. In three minutes, a single bird left the branch and flew over the lake. At 21:21, a single call was heard from the tree, immediately followed by a murrelet leaving the tree and flying over the lake. We were unable to climb to sufficient heights on this or other trees to ascertain whether young were present. There were no feathers or fecal material at the base of trees which would substantiate more prolonged occupancy.

Throughout the observational period, murrelets were rarely seen on the surface of the lake. The single occasion (18 June, 04:50) occurred when three birds were floating less than 10 m from shoreline. Foraging activity was not observed. It appeared that all were the same size and were able to fly equally well.

Discussion

It is generally known that Marbled Murrelets fly inland from the ocean at dusk and return to the sea by dawn (Sealy 1974a, 1975b; Summers 1975; Simons 1980; Carter and Sealy 1986). Our data indicate a relatively consistent pattern throughout summer with most flight activity occurring just before sunrise and just after sunset, roughly coinciding with the duration of civil twilight. At this latitude, there is no true darkness during June and July since astronomical twilight extends the entire period between sunset and sunrise (Anonymous 1946). However, we observed no substantive evidence for flight during the exceptionally low light levels beyond civil twilight. While visual detection of this flight would be difficult, the cessation of wing-beat sounds as evening darkness arrived and the onset of wing-beat sounds and vocalizations at dawn twilight strongly suggest an absence of "nocturnal" flight.

Copulation has not yet been observed in Marbled Murrelets and it is assumed that it occurs during darkness either on the ocean or near the nest site (Sealy 1975). The behaviour we observed of the two murrelets on branches is very suggestive of a mating sequence. The repeated short duration landings, associated wing-flapping and the equivalent behaviour on the following night, although not on successive nights, are all consistent with a ritualized behaviour which is very seasonally restricted. Egg-laying period in the Marbled Murrelet extends from 15 May to early July (Sealy 1974a) and thus the behaviour is also within the appropriate time period. That individuals were observed again on the tree at the end of July, in what may have been a feeding sequence, is further support. Each of these events in themselves could have numerous interpretations yet in concert, they support the initial impression of a mating event.

Marbled Murrelets exchange incubation duties during darkness and indirect evidence suggests this occurs every 24 hours (Sealy 1975, Simons 1980, Hirsch et al. 1981). Our observations which show flight activity at both dusk and dawn in early June (when incubation is probably occurring) raise the possibility for two exchanges per 24 hour period — a short nocturnal and a longer diurnal shift.

Adult murrelets are regularly observed flying inland from the ocean at dusk with fish in their bills during the prefledging period (Guiguet 1956; Sealy 1974b). Some of the flights observed at Coates Lake are probable feeding flights, in particular those which involved visits to the same tree on successive nights at the end of July. Where we were able to observe the arrival and departure from the branch, it ranged from 3-18 minutes. In Alaska, average length of time spent at the nest by the adult murrelet during four feeding flights was approximately 4 minutes (range 1 min 34 s - 8 min) (Simons 1984; Hirsch et al. 1985) and therefore the durations at Coates Lake were within the expected range for a feeding sequence. It is interesting that in

these presumed feeding flights, adults arrived at the lake at dusk in pairs. Sealy (1974a) also observed that during the prefledging period, pairs of adults occurred on the ocean during the day and flew inland at dusk, both with fish in the bills. This indicates that the prefledged young is left unattended during the day. There is indirect evidence that during darkness, the young is attended on some occasions but not on others. We observed pairs at dusk flying into the forest but within several minutes a single adult returned along the same flight path. As well, in July, evening seaward flights were observed about half as frequently as (and slightly later than) westward flights (Figure 2) further suggesting that some birds are overnighting in these forests. Yet, the observations at the end of July showed both adults arriving and leaving the tree at dusk. In both these instances, an additional feeding could occur at dawn if one or both of the adults returned. Although we have assumed that these flights represent breeding adults, we cannot exclude the possibility that individuals are non-breeders. However, if these were non-breeding adults, it seems likely that individuals would remain on the trees overnight rather than for several minutes.

The extensive circular and highly vocal flight activity over the lake surface, and extending well beyond sunrise, has not been previously described in Marbled Murrelets. Similar behaviour, in which up to 11 individuals were involved, has also been noted at a lake on the north-eastern corner of Graham Island (Reimchen, 1991). Previous studies on Marbled Murrelets indicate unidirectional flights at least near the ocean (Summers 1974; Simons 1980). The significance of this circular flight activity is unknown. Since the accompanying vocalizations came from birds in flight, possibly it represents a vocal stimulus or invitation to the prefledglings or attending adults in the nests. The departure of the single adult from the tree following a call from the lake is consistent with this suggesiton. That the circular flights and vocalizations were observed only in the morning and were absent in the evening is further suggestive of a "holding pattern" and vocal stimuli prior to the departure to the ocean.

Newly fledged Marbled Murrelets were observed at sea as early as 6 July at Langara Island (Sealy 1974b). While there remain suggestions that prefledged birds can make their way to the ocean on the ground or via streams (Drent and Guiguet 1961), it seems more probable that young fly directly from the nest to the sea (Sealy 1974a). Coates Lake, which is connected to the ocean via a wide stream offers substantive opportunity for stream migration. Yet, our observations, made throughout the pre-fledging period, indicated no evidence of young birds on the lake surface and we strongly suspect (in agreement with Sealy 1974a) that young murrelets fly directly from the nest to the ocean.

Occasional site records of Marbled Murrelets on freshwater lakes led Carter and Sealy (1986) to suspect that inland lakes near breeding areas may be regularly used as foraging or staging areas. Data on Coates Lake and those from Drizzle Lake (Reimchen and Douglas 1984a), demonstrate exceptionally infrequent use of the lake surface. Perhaps, as suggested for the marine foraging of the Red-throated Loons on these lakes (Reimchen and Douglas 1984b), the proximity of the nesting habitat to the ocean where prey of appropriate sizes are abundant, limits utilization of freshwater habitat.

Nesting areas of Marbled Murrelets, which include a diversity of habitats, are suspected of being most prevalent in old-growth forests (Savile 1972; H. Carter, personal communication). This is certainly supported from our observations at Coates Lake in which flight activity was common in the forested regions but rare in the sub-alpine. Direct access to large trees along the shore or adjacent to open areas in the canopy may make these areas favourable nesting sites. At Drizzle Lake, on the eastern regions of Graham Island, in a broad expanse of *Sphagnum* bog and scrub coniferous forests, Marbled Murrelet flight activity was exceptionally uncommon throughout the year including the periods when activity should have been greatest (Reimchen and Douglas 1984a). Yet an additional lake in the lowland region, which differs in being surrounded by several ridges with old-growth forest, murrelet flight activity (July 1986; Reimchen, 1991) was as extensive as that observed at Coates Lake.

Numbers of Marbled Murrelets occupying the area around Coates Lake cannot be reliably determined at present although estimates are possible. The east end of the lake, where most observations were made has at least seven birds as this is the number observed in flight at a single time. Since the observational area represents about 10% of the valley, and assuming similar densities around the lake, up to 70 birds are present. This could be a highly conservative estimate since only a fraction of the birds would be active at any single time. Comparable numbers may occur at a lake surrounded by moss-laden forests five km to the north of Coates Lake where extensive low level flight activity was also observed (June 1982, TER, personal observation). Nesting habitat of this species is subject to widespread geographical disturbance (Carter and Sealy 1984), and therefore the impending logging of these old growth forests is a major threat to the murrelet populations.

Of the twelve known nest sites of Marbled Murrelet discovered within the last century, all have been found largely by accident rather than as the result of a systematic search (Carter and Sealy 1986). Our observations on flight paths of Marbled Murrelets at Coates Lake have identified, over a relatively short period, seven trees where potential nests may be located. The fidelity of flight paths on successive nights provides a valuable technique of following and identifying destinations of individual birds. It was evident to us that with additional field observers at this locality, each concentrating on a different flight path, many more potential nesting trees would have been identified.

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A New Ruffed Grouse, Aves: Phasianidae: *Bonasa umbellus*, from Labrador, Canada

HENRI OUELLET

Canadian Museum of Nature, P.O. Box 3443, Station "D", Ottawa, Ontario K1P 6P4

Ouellet, Henri. 1990. A new Ruffed Grouse, Aves: Phasianidae: *Bonasa umbellus*, from Labrador, Canada. Canadian Field-Naturalist 104(3): 445-449.

A new subspecies of Ruffed Grouse (*Bonasa umbellus*) is described from southern Labrador and adjacent regions of Québec, Canada. *B. u. labradorensis* can be distinguished from *B. u. obscura* by the light buff overall suffusion of the ventral and dorsal regions, often including the tail. The ruffs are more frequently russet than dark brown. Males have statistically longer tarsi while both sexes have statistically broader bills than *B. u. obscura*.

L'auteur donne la description d'une nouvelle sous-espèce de la Gélinotte huppée (*Bonasa umbellus*) dont l'aire se situe dans le sud du Labrador et dans les régions adjacentes du Québec, Canada. *B. u. labradorensis* est différente de *B. u obscura* et s'en différencie par la teinte beige clair qui domine le plumage des régions ventrales et dorsales, y compris la queue. La collerette est plus souvent rousse que brune. Le tarse des mâles est statistiquement plus long que celui des femelles tandis que le bec des deux sexes est statistiquement plus large que chez *B. u. obscura*.

Key Words: Ruffed Grouse, *Bonasa umbellus labradorensis*, new subspecies, *B. u. obscura*, Labrador, Québec.

The early literature contains little information on the distribution of the Ruffed Grouse (*Bonasa umbellus*) in Labrador and adjacent parts of Québec (Townsend and Allen 1907; Macoun and Macoun 1909). Austin (1932: 173) reported that there were "no specimens on record" but predicted that "a series of specimens from this northeastern edge of the range of the species might prove the resident bird to be a race hitherto undescribed, . . .". Godfrey (1966, 1986) extended the range to southern Labrador (Goose Bay, Hamilton Inlet) and to the eastern north shore of the Gulf of St. Lawrence on the basis of observations and specimens obtained in 1915, 1919, and in the early 1960s.

In a study of geographic variation and revision of the subspecies of the Ruffed Grouse, Aldrich and Friedmann (1943) referred the population of central Québec to *B. u. umbelloides* on the basis of its coloration and size, although specimens from the eastern portion of the north shore of the Gulf of St. Lawrence or Labrador were not available to them. Later, Snyder and Shortt (1946) reexamined variation in eastern Canadian populations and concluded that the specimens from approximately the Manitoba-Ontario border to central Québec, including those from the eastern portion of the north shore of the Gulf of St. Lawrence, could be distinguished from *B. u. umbelloides*. They referred those birds to *B. u. canescens* as described by Todd (1940) on the basis of the consistently darker dorsal coloration of the specimens from Ontario and central Québec but pointed out that the name *canescens* was preoccupied. Todd (1947) renamed the population *B. u. obscura*.

Todd (1963) reviewed the situation and confirmed Snyder and Shortt's (1946) findings. He had more specimens available to him than Snyder and Shortt (1946) but none from Labrador and only two from the north shore of the Gulf of St. Lawrence: St. Margaret Falls, near Sept-Iles, Québec. Todd (1963: 257) concluded that *B. u. obscura* occurs in Québec and Labrador, north of approximately the mouth of the Saguenay River.

Several specimens have since become available from the eastern part of the north shore of the Gulf of St. Lawrence and, for the first time, a sizeable series from Labrador (Table 1). With the exception of the two specimens from eastern Québec collected early in the century (Bonne Espérance, Harrington Harbour), all the specimens from eastern Québec and Labrador have been obtained since the early 1960s. The large series from Labrador (47) obtained in the autumns of 1979 and 1980 through the courtesy of Stuart Luttich of the Wildlife Division of the Government of Newfoundland and Labrador forms the basis of the present study. The Ruffed Grouse is obviously uncommon in Labrador and adjacent parts of Québec and is usually restricted to deciduous stands of poplars (*Populus* sp.), alders (*Alnus* sp.), and willows (*Salix* sp.) along rivers or on islands, and on eskers. It is particularly difficult to observe in spring and early summer but appears to forage for food in small second-growth vegetation along roads in the fall.

Bonasa umbellus labradorensis, new subspecies

Holotype: The Canadian Museum of Nature, [formerly National Museum of Natural Sciences,

TABLE 1. Specimens of *Bonasa umbellus* from eastern Québec and Labrador.

	males	females	unsexed
Labrador			
Hamilton River Valley[1]	3	15	1
Goose River: Diver Island[2]	2	1	1
Churchill Falls[3]	1	2	
Grand Lake Road[4]	2	1	
Saltwater Pond[5]	2	1	
Churchill Falls Road[6]	6	4	2
Goose Bay area[7]	3	1	
Québec			
Duplessis Co.: Saint-Augustin[8]	1		
Duplessis Co.: Bonne-Espérance[9]			1
Duplessis Co.: Harrington Harbour[10]			1
	20	25	6

List of specimen numbers: [1]NMC-71043, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61; 47091; [2]NMC-71036, 40, 41, 42; [3]NMC-71027, 28, 29; [4]NMC-71020, 21, 22; [5]NMC-71037, 38, 39; [6]NMC-71018, 19, 23, 24, 25, 26, 30, 31, 32, 33, 34, 35; [7]NMC-71044; 78704, 05, 06; [8]NMC-49290; [9]NMC-16064; [10]NMC-8365.

National Museums of Canada] NMC 47091, male, from Goose Bay, about 7 km southwest of town site along Churchill River, Labrador, Canada; collected 15 June 1960 by Duncan MacKenzie.

Diagnosis: *Bonasa umbellus labradorensis* differs from *Bonasa umbellus obscura* in having a more buffy coloration particularly on the breast and back (Table 2), and significantly longer tarsi and a broader bill (Table 3).

Range: The southeastern part of the Québec-Labrador Peninsula, from approximately the Churchill River valley, Churchill Falls to Lake Melville, along the southern Labrador coast, the Strait of Belle Isle and the north shore of the Gulf of St. Lawrence, west to possibly Havre Saint-Pierre, Québec.

Habitat: Deciduous stands, bushy roadsides, alder and willow growths along rivers and streams and on islands, and young second-growth patches of deciduous species.

Measurements: See Table 2.

Specimens examined: In addition to the specimens listed in Table 1, a large series of specimens (143) in the Canadian Museum of Nature from Québec (north of St. Lawrence River) and Ontario was used for comparison purposes. Other large series totalling over 150 specimens were also studied to a lesser extent at the Royal Ontario Museum (Toronto), the Carnegie Museum of Natural History (Pittsburgh, Pennsylvania), and the Museum of Comparative Zoology, Harvard University (Cambridge, Massachusetts).

Etymology: This subspecies is named for the range in which it is known to occur. Labrador is presently restricted to the eastern portion of the Québec-Labrador Peninsula but the eastern part of the North Shore of the Gulf of St. Lawrence was known as Canadian Labrador before Newfoundland joined Canada in 1949.

Geographic Variation

The large series from Labrador as well as those specimens from adjacent areas of Québec in comparison to equally large series from other parts of Québec, north of the St. Lawrence River, and eastern and central-eastern Ontario, displays marked differences in several ways. Morphometric characters show statistically significant differences in male tarsal length, the Labrador sample having a

TABLE 2. Distribution of general colour classes in two series of *Bonasa umbellus*. Numbers in brackets [ ] indicate sample of *B. u. obscura* whereas other figures refer to *B. u. labradorensis*.

Colour classes	N	01	02	03	04	05
Breast						
Males	20 [15]	10 [0]	8 [0]	2 [1]	0 [14]	0 [0]
Females	25 [15]	2 [0]	13 [0]	10 [2]	0 [3]	0 [10]
Back						
Males	20 [15]	9 [0]	10 [0]	1 [1]	0 [14]	0 [0]
Females	25 [15]	1 [0]	18 [0]	6 [0]	0 [3]	0 [12]

TABLE 3. Measurements (in mm) of *B. u. labradorensis (lab.)* and *B. u. obscura (obs.)*. Weight is in grams. [1]chord of the wing; [2]exposed culmen; [3]culmen width at level of exposed culmen; [4]weights have been obtained from another sample in the range of *B. u. obscura*. S.D. = standard deviation; S.E. = standard error of the mean. *indicates a statistically significant difference between means as follows: $*t_{05[33]} = 4.27$; $**t_{05[33]} = 4.76$; $***t_{05[36]} = 23.33$.

		N	Range	Mean	S.D.	S.E.
Males						
Wing[1]	(*lab.*)	20	170.1-185.2	179.50	3.92	0.88
	(*obs.*)	15	172.2-186.9	181.77	4.34	1.12
Tail	(*lab.*)	19	119.7-163.8	145.10	10.71	7.38
	(*obs.*)	13	120.0-175.9	154.77	15.29	4.24
Culmen[2]	(*lab.*)	20	13.6-18.0	15.10	1.03	0.23
	(*obs.*)	15	13.4-18.7	15.73	1.43	0.37
Tarsus	(*lab.*)	20	42.5-46.9	* 44.40	1.13	0.25
	(*obs.*)	15	40.3-44.5	42.68	1.28	0.33
Width[3]	(*lab.*)	20	9.1-11.9	** 10.70	0.67	0.15
	(*obs.*)	15	9.1-10.7	9.85	0.43	0.11
Weight	(*lab.*)	19	550.6-841.3	637.7	75.89	17.41
	(*obs.*)[4]	15	447.5-674.1	598.1	56.82	14.67
Females						
Wing[1]	(*lab.*)	23	165.4-181.6	174.7	4.39	0.92
	(*obs.*)	15	167.6-183.2	175.2	5.22	1.35
Tail	(*lab.*)	21	112.1-135.3	128.6	5.98	1.31
	(*obs.*)	15	121.1-167.4	130.7	11.71	3.02
Culmen[2]	(*lab.*)	23	12.0-17.4	14.9	1.18	0.25
	(*obs.*)	14	13.6-16.3	15.0	0.91	0.24
Tarsus	(*lab.*)	23	38.9-43.3	40.7	1.22	0.25
	(*obs.*)	15	37.8-45.0	41.0	2.16	0.56
Width[3]	(*lab.*)	23	9.1-11.6	*** 10.4	0.67	0.14
	(*obs.*)	15	9.2-10.3	9.7	0.33	0.24
Weight	(*lab.*)	23	479.9-684.6	567.4	53.82	11.22
	(*obs.*)[4]	15	463.0-595.9	520.9	44.30	11.44

longer tarsus as well as a broader bill (culmen width); females also have a broader bill (Table 2).

To compare a large series of specimens from central and eastern Ontario and Québec, north of the St. Lawrence River, with the Labrador series five colour classes were recognized on the basis of the general coloration of the specimens, but primarily the ventral and dorsal regions. A specimen representative of each class has been selected as a reference and its catalogue number is indicated following the class it represents. CLASS 01 [NMC 47091] contains the specimens with a heavy suffusion of buff and light buffy brown markings on the under parts, and a light rusty band around the neck. The back has an overall suffusion of reddish buff and few dark brown markings. CLASS 02 [NMC 71033] resembles the previous category but the ventral markings are heavier and darker, whereas the overall buffy suffusion of the under parts is much reduced. The back has darker and more prominent brown markings while the reddish is less buffy. In CLASS 03 [NMC 71021] the ventral markings are heavier and more pronounced than in the two previous classes, particularly around the neck. The buffy suffusion is totally absent. On the back the dark brown markings are heavier and more numerous than in any of the other classes. CLASS 04 [NMC 59732] has light brown ventral markings and heavy dark brown markings around the neck. The back has fewer dark markings but many more lighter markings and the background coloration of many rump feathers is mainly dark russet. CLASS 05 [NMC 36734] has darker brown ventral markings than the previous class but its neck markings are lighter. The dorsal parts have fewer dark brown markings and are more greyish overall than any of the other classes. Table 3 summarizes the distribution of the colour classes and shows that most of the specimens of *B. u. labradorensis* can be assigned to CLASSES 01 and 02 and fewer to CLASS 03 whereas the majority of the specimens of *B. u. obscura* fall in CLASSES 04 and 05.

Russet ruffs are more frequent in *B. u. labradorensis* in both sexes as shown in Table 4. The general buffy coloration of the tail is found also on a large proportion of the Labrador birds of both sexes whereas gray is more frequent in *B. u. obscura* (Table 5).

In summary, *B. u. labradorensis* can be separated from *B. u. obscura* by the light buffy overall suffusion observed primarily on the ventral and dorsal regions, often including the tail. The ruffs are

TABLE 4. Distribution of ruff colour in two series of *Bonasa umbellus*.

	Males		Females	
	labradorensis	*obscura*	*labradorensis*	*obscura*
Black	9 (45%)	13 (87%)	10 (40%)	15 (100%)
Russet	11 (55%)	2 (13%)	15 (60%)	0 (0%)

TABLE 5. Distribution of tail colour in two series of *Bonasa umbellus*.

	Males		Females	
	labradorensis	*obscura*	*labradorensis*	*obscura*
Gray	10 (53%)	10 (77%)	7 (33%)	9 (60%)
Buffy	9 (47%)	3 (23%)	14 (67%)	6 (40%)

more frequently russet than dark brown. The males have longer tarsi and both sexes have broader bills than *B. u. obscura*. No area of intergradation has been identified and the few intermediate specimens (Tables 3 and 4) come from the sample as described in Table 1.

Discussion

As predicted by Austin (1932: 173), even in the absence of any specimen, the Ruffed Grouse of Labrador proved to be subspecifically distinct from adjacent populations in the southern part of the Québec-Labrador Peninsula, north of the St. Lawrence River. The Labrador population would undoubtedly have been described earlier if specimens had been available because its coloration is so different from that of adjacent populations.

B. umbellus labradorensis appears to be relatively well isolated from other populations to the west by a general lack of suitable habitats. The patches of habitat used by this bird are often isolated from one another by large tracts of coniferous forests or, in the higher areas, by extensive tracts of taiga. Birds are therefore mainly restricted to river valleys, reducing their ability to move over long distances, and are relatively isolated from contiguous populations which may explain the apparent lack of intergradation.

The origin of these birds probably goes back to one of the post-glacial periods (Rand 1948) of climatic warming and amelioration which allowed different types of forests to develop in Labrador and adjoining areas and form a nearly continuous cover with more southern forest types (Ogden 1977; Huntley and Webb 1989; Bennett 1985; Webb 1988). It can be argued that when climatic conditions deteriorated with ensuing changes in the forest vegetation the Labrador and adjacent populations of the Ruffed Grouse were no longer capable of moving freely in all directions and eventually became isolated in the suitable habitats that they were occupying.

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Multiple Nursing in Free-Living Muskoxen, *Ovibos moschatus*

B. Ann Tiplady

Alaska Cooperative Wildlife Research Unit, Univeristy of Alaska, Fairbanks, Alaska 99775
Present address: P.O. Box 20572, Juneau, Alaska 99802

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Multiple nursing by two free-living Muskox (*Ovibos moschatus*) cows was observed throughout the summer of 1984 in western Alaska. Each cow regularly nursed as many as four calves at once. In 1985, the same cows seemed to nurse only their own calves. The indiscriminate multiple nursing possibly was due to confusion over calf identity at the time of birth.

Key Words: Muskox, *Ovibos moschatus,* nursing behaviour, multiple nursing.

The bond between a female ungulate and her young usually is exclusive (Spencer-Booth 1970; Lent 1974) and females of most species nurse only their own young. Most female ungulates do not tolerate the young of others, and avoid, threaten, or attack these strange young when approached by them. Such aggressive reactions have been reported in several species of deer (Lent 1966; Clutton-Brock et al. 1982; Hirth 1985; Van Mourik 1986), domestic and wild sheep and goats (Hersher et al. 1963; Spencer-Booth 1970; Geist 1971; Grubb 1974; Hulet et al. 1975), horses (Tyler 1972), and elephants (Lee 1987; Rapaport and Haight 1987). Despite this hostile response, the young of many ungulate species frequently attempt to suckle from strange females, usually without success (Lent 1966; Spencer-Booth 1970; Tyler 1972; Clutton-Brock et al. 1982). Moreover, when a female does cross-nurse (nursing of strange young) she often seems unaware that the suckling young are not her own. Typically, when she discovers that strange young are suckling she immediately ends the nursing bout and often threatens or attacks the strange young (Lent 1966; Espmark 1971; Geist 1971; Tyler 1972; Lee 1987).

Muskoxen (*Ovibos moschatus*) also have exclusive mother-young bonds. Cows are intolerant of strange calves and may chase them (Alendal 1979), sometimes even using their horns to flip the calves away (Jingfors 1984; Gray 1987). Alendal (1979) never observed cross-nursing in introduced wild Muskoxen in Norway. Jingfors (1984) observed only two multiple-nursing bouts (nursing more than one calf at once) in 757 nursing bouts in several large herds of wild Muskoxen in both Alaska and arctic Canada. He also saw Muskox calves trying to suckle from strange cows, both while the cows' own calves were suckling and at other times; all these cross-suckling attempts were refused by the cows. P. Groves (personal communication) occasionally saw captive Muskox cows nurse more than one calf at once. These calves seemed to suckle opportunistically from strange cows; when the cows realized that strange calves were suckling they immediately ended the bouts by spinning around and chasing or butting the calves.

In 1984 I observed an exception to these reports in a small herd of wild Muskoxen in which two cows routinely nursed three or four calves at once. I hypothesize that this unusual behaviour was caused by confusion over calf identity at the time of birth.

Study Herd and Methods

The study herd developed from a small group of Muskoxen, a mature cow (Cow 1), two yearling cows (Cows 2 and 3), and a yearling bull, that travelled to their current range about 22 km north of Nome, Alaska (64°30′N, 165°25′W) after being released by the Alaska Department of Fish and Game in March 1981 (Grauvogel 1984). Cow 1 gave birth to a calf (Cow 4) in 1981, but no calves were born in 1982. A mature bull joined the herd in 1982 (T. Smith, personal communication) and Cows 1 and 3 each gave birth to a calf in 1983. Four calves were born in 1984, and three calves were born in 1985. The relationship of Cows 1, 2, and 3 is unknown; it is possible that either Cow 2 or Cow 3 was a daughter of Cow 1.

As part of a study of Muskox nursing behaviour, an assistant and I observed the study herd for 118 hours over 22 days from mid-May through July 1984. Another assistant and I observed the same herd for 8 hours over three days in late-May 1985. We used spotting scopes to watch the animals, usually from a facing hillside. We identified the four cows individually by horn size and shape, but

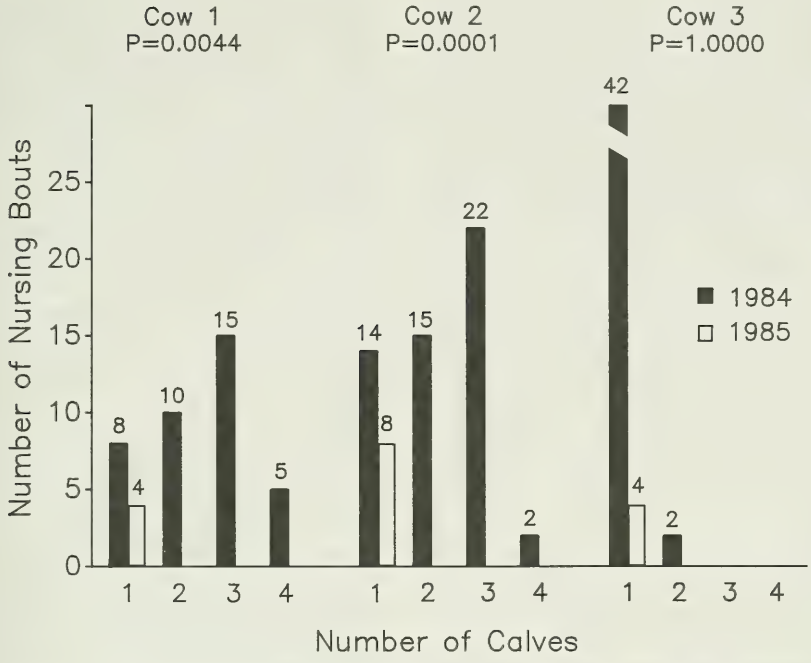

FIGURE 1. The number of successful nursing bouts for each muskox cow involving one, two, three, or four calves in 1984 (solid bars) and 1985 (open bars). Fisher's Exact Test was used to compare the numbers of single- and multiple-nursing bouts in 1984 to 1985 for each cow.

were unable to identify individual calves. Data were collected during continuous observations of the focal group (Altmann 1974), which was the three nursing cows and all calves. The time, duration, cow identity, and number of calves involved were recorded for each nursing bout. The duration of nursing bouts was timed with a stopwatch to the nearest second. Timing began when a calf first bunted the udder and ended when the cow ended the bout. Observations were spoken into a tape recorder and later transcribed into a notebook.

I have used the term nursing for the mothers' role in milk transfer, and suckling for the role of the young, following Cowie et al. (1951). I defined a successful nursing bout as any bout with a duration of at least 5 seconds. With this definition I hoped to eliminate from the sample unsuccessful suckling attempts, and bouts so short that the calf received no milk. The longest observed nursing bout was 104 seconds; however, all but two bouts were less than 75 seconds long. To compare each cow's behaviour in 1984 to that in 1985, the numbers of single- and multiple-nursing bouts were compared using a two-tailed Fisher's Exact Test.

Observations

In 1984 there were four cows and four calves, but only three cows nursed calves. The oldest cow (Cow 1) and one of the 4-year-old cows (Cow 2) routinely nursed as many as four calves at the same time. The second 4-year-old cow (Cow 3) usually nursed only one calf. We never saw the 3-year-old cow (Cow 4) nurse any calves. All four calves born in 1984 were alive in late-May 1985. Cows 1, 2, and 3 each had a new calf in late-May 1985, but Cow 4 did not. We did not see any multiple nursing in 1985; each cow nursed only one calf. A total of 134 successful nursing bouts with a known number of calves suckling was observed in 1984, and 16 successful nursing bouts were observed in 1985 (Figure 1). Although sample sizes were small in 1985, the single-nursing behaviour of Cows 1 and 2 in 1985 was significantly different from their multiple-nursing behaviour in 1984 (Cow 1, $p = 0.0044$; Cow 2, $p = 0.0001$; Figure 1). There was no difference between years for Cow 3 ($p = 1.0$; Figure 1), who usually nursed only one calf in both years.

Multiple nursing by Cows 1 and 2 persisted throughout the 1984 observations. A typical mutliple-nursing bout began when Cow 1 or 2 rose

after lying. One calf would run to her and begin bunting and suckling. A second calf, a third, and sometimes the fourth would join and also suckle. The second foster cow often would rise about this time and the calves would run to her and suckle again. Any number of calves, from one to four, would start any given suckling bout, and many bouts that started with only one calf ended with two, three, or four calves. All the calves that suckled from the first cow would not always suckle from the second, and sometimes a calf that had missed the first bout would suckle from the second cow. During these multiple-nursing bouts, the vigorous bunting by the calves often lifted the cow and pushed her backwards or in circles. The cows often smelled the anogenital area of each calf while it suckled, suggesting that they had the opportunity to identify the calves.

Discussion

Cows 1 and 2 together raised three calves, and contributed to raising the fourth. I assumed that Cow 3, who usually nursed only one calf, nursed only her own calf. These observations raised two questions: which cow produced the fourth calf, and why did Cows 1 and 2 nurse calves indiscriminately?

It is unlikely that the fourth calf was a twin because twins are very rare in Muskoxen. Tener (1965) reported that twinning occurred only exceptionally, and Lent (1978) found no reports of viable twins in Muskoxen. Wilkinson (1971) reported only one case of twins, which were stillborn, in 74 births in captive Muskoxen. Living twin calves have been reported in captive Muskoxen (Yakushkin 1984; P. Groves, personal communication) but none lived to one year of age. It seems more likely that the fourth calf was produced by Cow 4, abandoned, and fostered by Cows 1 and 2. However, neither twinning nor abandonment explains why Cows 1 and 2 routinely nursed as many as four calves.

Riedman (1982) showed that care of strange young by female mammals is seen primarily in groups of related females, suggesting some form of kin-selection. However, Muskox herds are unstable, joining and splitting so that cows found together at one time may later be found in different herds (Reynolds 1984; Gray 1987). Such constant change in herd membership would preclude the development of fostering due to kin-selection. Furthermore, cross-nursing is uncommon even in those ungulates that live in groups of relatives. Elephants (*Loxodonta africana* and *Elaphus maximus*) live in relatively stable groups of related females, but they do not nurse calves of other females when they have their own suckling calves at foot (Lee 1987; Rapaport and Haight 1987), and Red Deer (*Cervus elephus*) rarely nurse strange calves, even though they often associate with relatives (Clutton-Brock et al. 1982). Thus, female ungulates do not normally nurse strange young, even those to which they are related.

Females may foster strange young by mistake (Riedman 1982). The multiple-nursing behaviour observed in 1984 is very like that described by Hudson (1977) and Kent (1984) for domestic cows (*Bos taurus*) that are confused about which calves are their own. Female ungulates with more than one young normally nurse them synchronously, allowing suckling to begin only when all young are present (Grubb 1974; Lent 1974; Hulet et al. 1975). Hudson (1977) found that cows each having four strange calves introduced to them before any exposure to their own newborns nursed only these foster calves, and did so synchronously, so that each calf suckled for the same length of time. However, when new calves were introduced to cows after exposure to their own newborns, they allowed both their foster calves and strange calves to suckle (Hudson 1977; Kent 1984) during non-synchronous suckling bouts, so that individual calves suckled for different lengths of time (Hudson 1977).

The critical period after birth during which female ungulates learn to identify their offspring is short (Lent 1974), but during this time females are attracted to any newborns and may accept them as their own (Arnold and Morgan 1975; Hudson and Mullord 1977; Poindron et al. 1980). Females of many species isolate themselves from herd members before giving birth (Riedman 1982; Shackleton and Shank 1984), and this may allow the mother-young bond to form without interference (Arnold and Dudzinski 1978). However, Muskoxen typically do not leave the herd before calving (Tener 1965; Jingfors 1984; Gray 1987) and therefore may be subject to interference from other Muskoxen. Lent (1974) saw Muskoxen interacting with cows and their newborns, even during birth. I suggest that Cows 1 and 2 calved at the same time in 1984 and encountered each others' calves before the correct cow-calf bonds had formed. Thereafter, they could not identify their own calves, and did not differentiate between calves when nursing. Presumably, Cow 3 encountered only her own calf during the critical bonding period; subsequently she usually nursed only her own calf.

In May 1984 we could not distinguish between the four calves, but by July we could identify one larger calf and one smaller calf among the four, suggesting that they had different growth rates. Hudson (1977) and Rosecrans and Hohenboken (1982/83) showed that cross-suckling causes great

variability in calf growth. Grubb (1974) described a Soay lamb (*Ovis aries*) and Milne (1987) described a Red Deer calf that grew faster than their peers because each suckled from two females. Cow 3 seemed to be the mother of the largest calf; her calf would have received all her milk and milk from Cows 1 and 2 as well, explaining its larger body size.

These observations support Jingfors' (1984) suggestion that multiple nursing does not necessarily indicate twinning in Muskoxen. Furthermore, they suggest that assumptions about the relationship between a cow and calf must be made with suitable caution.

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Status of the Gulf of St. Lawrence Aster, *Aster laurentianus* (Asteraceae), in Canada*

FRANCINE HOULE[1] and ERICH HABER[2]

[1]Université du Québec à Trois-Rivières, Département de Chimie-Biologie, C.P. 500, Trois-Rivières, Québec G9A 5H7
[2]Botany Division, Canadian Museum of Nature, P.O. Box 3443, Station "D", Ottawa, Ontario K1P 6P4

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The Gulf of St. Lawrence Aster (*Aster laurentianus*) is a rare halophyte, endemic to coastal habitats in the gulf of St. Lawrence. Its historic range consists of 10 sites, based on verified collections, in New Brunswick, Prince Edward Island, and Quebec (Magdalen Islands). No voucher could be located to verify a report from Kouchibougouac National Park N.B. In addition, four new sites were discovered on the Magdalen Islands during field work for this study. In total, fewer than 1000 plants were recorded at 13 extant sites (no plants were found at Grand Tracadie, PEI). Only 12 plants were seen at the type locality in PEI National Park, with the largest numbers occurring at sites on the Magdalen Islands (at least 200 at each of two of the largest populations).

Key Words: *Aster laurentianus*, rare endemic, Gulf of St. Lawrence, Canada.

The Gulf of St. Lawrence Aster, *Aster laurentianus* Fernald, is a rare endemic, part of a small group of widespread annuals in the section *Conyzopsis* found in saline and subsaline habitats. The plants are smooth, hairless and somewhat fleshy, up to 30 cm tall with linear-lanceolate to spatulate, generally sessile leaves. The rayless white to pink flower heads are surrounded by leafy bracts, with the pappus bristles extending prominently above the florets (Figure 1).

The species was first collected by John Macoun on 5 September 1888 at Brackley Point, PEI, in what is now Prince Edward Island National Park. He identified his specimens and distributed duplicates as *Aster subulatus* Michaux. M. L. Fernald and coworkers subsequently collected plants from the same locality on 31 August 1912. Fernald (1914) described these as the new species *Aster laurentianus*. This aster has been treated as being synonymous with the wide-ranging North American and Eurasian species *A. brachyactis* Blake by Boivin (1966-67) and others, and has also been treated as a subspecies of this species (Jones 1984). An examination of isotypes and topotypes by Catling and McKay (1980) and the work of FH on the morphology, phenology, and ecology of *A. laurentianus* (Houle 1988) support the recognition of this aster as a separate species.

Distribution

Aster laurentianus is an endemic of the Gulf of St. Lawrence (Figure 2). Herbarium specimens were verified from ten of the eleven historic localities for this species: 2 localities in NB, 4 in PEI, and 4 in Quebec (Magdalen Islands). Four new localities were found by FH on the Magdalen Islands during the field seasons of 1983-1986. A specimen collected in 1979 in Kouchibougouac National Park (*Munro 1784*) and identified as *A. laurentianus* by Munro could not be located to verify its identity.

According to Fernald (1925, 1951), *A. laurentianus* is an endemic of unglaciated sites in the Gulf. Houle (1988), however, considers *A. laurentianus* to have evolved more recently from *A. brachyactis* during post-glacial times. Fernald (1914, 1925, 1950) also recognized three insular varieties in *A. laurentianus*: var. *laurentianus* is confined to Prince Edward Island and the southern end of the Magdalen Islands, var. *magdalenensis* is restricted to the northern end of the Magdalen Islands, and var. *contiguus* occurs along the shores of northern New Brunswick. Although the three morphotypes can be recognized in Fernald's collections, the more abundant material available to the senior author does not support the recognition of these varities. The diagnostic

*Based on a COSEWIC status report by the senior author. Copies of the complete report are available at cost from the Canadian Nature Federation, 453 Sussex Drive, Ottawa K1N 6Z4. Vulnerable status was assigned by COSEWIC 19 April 1989.

FIGURE 1. Habit of *Aster laurentianus* found along the shore at Ile de la Grande Entrée, Magdalen Islands (Same plant as in foreground of figure 3).

characters used to distinguish these varieties have been shown to be influenced by conditions of culture (Houle 1988). The variability seen in this species is a reflection of its phenotypic plasticity rather than of genetic differentiation.

Habitat

Aster laurentianus is a coastal pioneer, growing on brackish sand or mud around ponds in dune slacks, on sand flats behind dunes, or drier sites in saline marshes, or on sandy beaches in protected coves (Figure 3). The sites are on fine or coarse sands, gravel, or clay with variable silt cover. These soils have a mean pH of 5.5 (Grandtner 1967). On Prince Edward Island, the aster has been found on Culloden and Kildare sandy loams (Erskine 1960).

The general maritime macroclimate of the region is one with mean July temperatures of 18-20°C and -5 to -10°C in January, with high humidity, frequent fogs and regular winds (Thannheiser 1984). The plants grow in full sunlight near sea level, in habitats of variable salinity that are flooded only by exceptionally high water levels and storm floods and are relatively protected from winds.

General Biology

Aster laurentianus is an annual herb. In the greenhouse, its development is very rapid. It requires only 2-3 months to fruit compared with 6-8 months for its closest relatives, *A. brachyactis* and *A. frondosus* (Nutt.) T. & G. Under uniform growing conditions, *A. laurentianus* is also generally a smaller plant with fewer and smaller basal leaves and flower heads than these same two species (Houle 1988). Flowering occurs in the field during late August to mid September, with fruits being present by late September and dispersal occurring in late October.

Fruit set in the greenhouse is about 50-60%, with ripe fruit having been observed at all natural populations. Dispersal is by wind and water. Under laboratory conditions, seeds are still viable after three years, with a probable longevity of at least 10 years, as judged by culture data of the related species *A. brachyactis*. Seeds require no dormancy, scarification, or salt in the substrate. In vermiculite, 80% of the seeds germinate after two weeks (Houle 1988).

Aster laurentianus, like the other two species of section *Conyzopsis, A. brachyactis* and *A. frondosus*, is self-compatible (Houle 1988). Its floral morphology is similar to that of *A. brachyactis* and is characteristic of self-pollinated species of asters. Ligules and nectaries are small or absent, styles are generally included in the staminal tube, and the pappus overtops the corollas before anthesis. In contrast, *A. frondosus* is frequently visited by insects in the field and is probably also commonly cross-pollinated.

Artificial cross-pollination using *A. laurentianus* as the female parent has produced fertile F_1 hybrids with *A. brachyactis* and *A. frondosus* as male parents (45 and 7 hybrids respectively, Houle 1988). Self-pollination by these hybrids resulted in

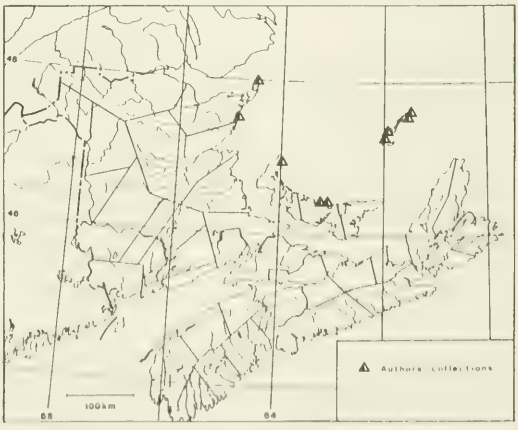

FIGURE 2. Distribution of all extant populations of *Aster laurentianus* as verified by collections made by Houle. Not all sites could be plotted as separate symbols.

FIGURE 3. Shoreline habitat of *Aster laurentianus* at Ile de la Grande Entrée, Magdalen Islands. Arrow points to the aster.

F_2 hybrids. Enzymatic studies (Houle 1988) and the higher degree of crossability between *A. laurentianus* and *A. brachyactis* indicate a closer genetic affinity between these two species. Reciprocal crosses, however, have been unsuccessful, suggesting sporophytic cross-incompatibility. In nature the three species are reproductively isolated because they are predominently self-pollinating and because of the geographical isolation of *A. laurentianus.*

Population size and trends

Thirteen localities have been confirmed by the senior author. A search for the aster in suitable habitats of Kouchibougouac National Park, where it has been reported to occur, was unsuccessful. Table 1 lists the 13 verified localities and the number of plants individually counted or estimated to occur at the sites.

Fewer than 1000 plants have been counted in total at 13 of the extant populations known from Prince Edward Island (23 plants), New Brunswick (200) and Quebec (Magdalen Islands, 661). A search for the aster at Grand Tracacie, PEI, a verified historic locality, was unsuccessful.

Limiting factors

The rarity of *A. laurentianus* in suitable maritime habitats probably reflects its relatively low survival rate in nature in spite of its relatively high germination capability, at least as demonstrated under controlled conditions.

No clear evidence of threats to the survival of *A. laurentianus* has been noted. Plants were not found at Brackley Point in Prince Edward Island National Park, the type locality for the species, but another population was located nearby at Brackley Beach. This can be interpreted as representing a natural displacement of an annual species. However, critically low population numbers and high human pressure do exist at the Park. Future developments in the Park should take into account the importance of the population at Brackley Beach.

Special significance of the species

Aster laurentianus has special significance because it is endemic to the Gulf region and because it occurs in coastal habitats with other provincially rare species such as: *Lomatogonium rotatum* L. in NB (Hinds 1983), *Calamagrostis neglecta* (Ehrh.) Gaertn., Mey. & Scherb. in NS (Maher et al. 1978), *Rumex persicarioides* L. in NB and NS (Hinds 1983; Maher et al. 1978), and *Stellaria humifusa* Rottb. in NS and Que (Maher et al. 1978; Bouchard et al. 1983).

Protection

No official protection is afforded this species in Canada. It is listed as rare in New Brunswick

TABLE 1. Numbers of plants of *Aster laurentianus* counted or estimated by Houle between 1983-1986 at 13 sites.

Locality	Number of Plants
PRINCE EDWARD ISLAND	
Queens Co.: Brackley Point (Type locality)	12
: Dalvay	1
Prince Co.: Tignish	10
NEW BRUNSWICK	
Gloucester Co.: Miscou Is.	100
: Tracadie	100
QUEBEC (Magdalen Islands)	
Amherst Is.	200
Coffin Is.: Grande Entrée	1
Grindstone Is.: Etang du Nord	60
Ile de l'Est: Cap de l'Est	30
: Old Harry	200
Ile de la Grande Entrée: north of Bassin aux Huîtres	50
: east of Basin aux Huîtres	100
Ile du Cap aux Meules: Cap de l'Hôpital	20
Total	884

(Hinds 1983) and has a national priority rank of 2 by virtue of its localized endemic nature and an overall ranking of 3 because of the absence of demonstrated threats to the species (Argus and Pryer 1989). These rankings are based in part on guidelines developed by The Nature Conservancy (USA).

Evaluation of status

Aster laurentianus is presently known to occur at 13 localities in the Gulf of St. Lawrence region. At four of these sites there are fewer than 20 plants present at each, with the total number of plants counted or estimated at 13 sites being less than 1000. In view of the relatively few localities known for this species and the low number of plants present, the species has been designated as vulnerable by COSEWIC.

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Western Grebe, *Aechmophorus occidentalis*, Wintering Biology and Contaminant Accumulation in Commencement Bay, Puget Sound, Washington

CHARLES J. HENNY, LAWRENCE J. BLUS, and ROBERT A. GROVE

U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 480 SW Airport Road, Corvallis, Oregon 97333

Henny, Charles J., Lawrence J. Blus, and Robert A. Grove. 1990. Western Grebe, *Aechmophorus occidentalis*, wintering biology and contaminant accumulation in Commencement Bay, Puget Sound, Washington. Canadian Field-Naturalist 104(3): 460–472.

Western Grebes wintering at the head of Commencement Bay (bordering the waterways) accumulated significant amounts of mercury, arsenic, DDE, PCBs, chlordanes, and perhaps cadmium and HCB between 17 October 1985 and 6 February 1986. No change in selenium or lead was detected, but copper declined significantly. Western Grebes were likely to accumulate even higher levels of certain contaminants because they remained in Commencement Bay for an additional 3 months after the final collection. Remige moult and bursa length were used to separate five individuals believed to represent one age class, from the remainder of the October collection. These birds, perhaps nonbreeders spending one continuous year in Puget Sound, contained the 5 highest PCB, 5 of the 8 highest DDE, and 2 of the 3 highest mercury concentrations. No evidence was found in the literature to suggest the contaminant concentrations we reported would adversely impact the Western Grebe population. As expected, lipid content of carcasses increased significantly from October (15.5%) to February (28.8%).

Key Words: Western Grebe, *Aechmophorus occidentalis*, Puget Sound, Commencement Bay, DDT, PCBs, mercury, selenium, arsenic, copper, lead, cadmium, moult, weight, lipid cycle.

An estimated 33 000 seabirds nest in Puget Sound, 330 000 birds winter, and several million shorebirds and other waterbirds stop during migration (U.S. Fish and Wildlife Service 1982). Commencement Bay and the Tacoma Waterways are in a highly industrialized area of Puget Sound adjacent to Tacoma, Washington (Figure 1). This area receives large amounts of organic and metal contaminants, and significant concentrations are retained by the sediments and biota (Malins et al. 1980; Dexter et al. 1981; Riley et al. 1981; Tetra Tech 1985; Bloom and Crecelius 1987). Sediment toxicity tests with invertebrates show a patchy distribution of both acutely toxic and non-toxic sediments in the Tacoma Waterways while Commencement Bay sediments are generally not toxic (Swartz et al. 1982). The distribution and abundance of amphipods, particularly those in the pollution-sensitive family Phoxocephalidae, indicate an overall higher level of pollution stress in the waterways than in the Bay (Swartz et al. 1982). Sediment contamination was highest in the Sitcum and Hylebos Waterways, intermediate in Commencement Bay, at the entrances to the Tacoma Waterways and in the outer reaches of the Blair and Hylebos Waterways, and lowest at the Blair Waterway turning basin, the mouth of the Puyallup River and at a reference site near Brown's Point (Schults et al. 1987).

Although knowledge of contaminant concentrations in waterbirds and their food remains limited, a few marine birds from Puget Sound were analyzed (Riley et al. 1983). These included nestling Glaucous-winged Gulls (*Larus glaucescens*), nestling Pigeon Guillemots (*Cepphus columba*), and five adult Great Blue Herons (*Ardea herodias*).

The Western Grebe (*Aechmophorus occidentalis*) is a migratory species that breeds throughout much of western North America and winters primarily along the Pacific Coast (A.O.U. 1983, 1985). They were first described from specimens collected at Puget Sound in 1858 (Baird et al. 1858; Deignan 1961) and have persisted as common winter residents (late September — early October through April), with some nonbreeders remaining in the summer (Larrison and Sonnenberg 1968; Angell and Balcomb 1982). Twenty grebes collected on 17 October 1985 and another 20 collected from the same population on 6 February 1986 — 112 days later after wintering in the area — provided the data source in this study. The objectives of our research were: (1) to determine if Western Grebes accumulated selected contaminants while wintering in Commencement Bay, (2) to review the literature on sediment enrichment by selected contaminants, and (3) to review the literature on contaminant loads in fish. Western Grebes in Puget Sound feed primarily upon fish including Herring (*Clupea pallasii*), Candlefish (*Thaleichthys pacificus*), Sea Perch (*Cymatogaster sp.*), probably Pacific Tomcod (*Microgadus proximus*), and apparently Blennies (Stichaeidae) (Palmer 1962). With the exception of polychlori-

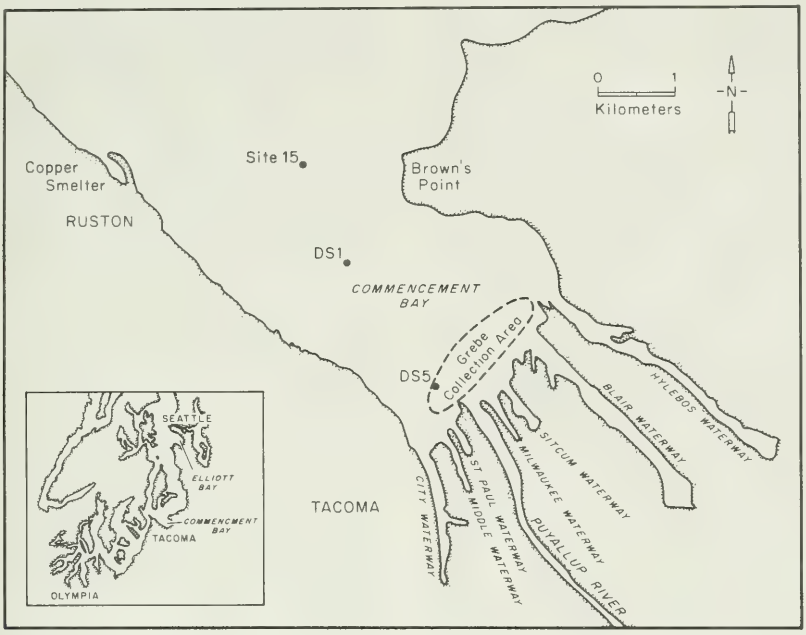

FIGURE 1. Location of Commencement Bay and Tacoma Waterways, Washington.

nated biphenyls (PCBs) and hexachlorobenzene (HCB) in livers, fish residue information from Commencement Bay was limited to edible parts for human consumption (muscle) and therefore, does not reflect whole body burden which would be higher if liver and other organs were included. However, the data available provide useful comparative information. The contaminants studied were from the US EPA list of priority pollutants and included several previously found in high concentrations in Commencement Bay sediments (selenium, copper, arsenic, mercury, lead, PCBs, and organochlorine pesticides including HCB which also has an industrial source).

Study Area

Commencement Bay is a hydrologically complex, deep-water embayment (170 m maximum depth) in Puget Sound (Figure 1). The Puyallup River is the major source of freshwater to the Bay, supplying an average of 5800 m^3/min of silt-laden water (Dexter et al. 1981). Dredge material disposal occurred at station DS5 from 1971 through 1975, and dredge material and industrial waste disposal has taken place at station DS1 since 1972 (Schults et al. 1987). The head of the Bay, bordering the waterways, is heavily industrialized with chemical manufacturing plants, a metals reclamation yard, a pulp mill, log holding areas, petroleum refineries, marinas, ship repair/manufacturing facilities, pole treating yard, tanners, food processors, and other activities associated with marine commerce. The Western Grebes we studied wintered within 1 km of shoreline at the head of Commencement Bay (Figure 1).

Methods

Grebes were collected from a boat with a shotgun (steel shot), immediately placed in aluminum foil and frozen for later processing. During the processing, the bursa of Fabricius, a cloacal diverticulum, was measured to the nearest mm in an attempt to age the grebes. The bursa is prominent in most young birds and usually reaches maximum size within 2 or 3 months of hatching and then regresses, but depending on the species, it may or may not disappear by the time sexual maturity is reached (Taber 1969). All grebes were sexed by observing the gonads. Bill length (exposed culmen), length of lobe of hind toe, wing length (notch to tip), stomach contents, gonad condition, and whole body weight were recorded. General notes were taken on plumage. In addition, the carcass weight (with all feathers plucked, and without bill, legs, and all internal organs) was recorded. During the processing, samples were placed in chemically cleaned jars and refrozen for later chemical analyses at the Patuxent Wildlife Research Center in Laurel, Maryland. Each liver and kidney sample was homogenized in a virtis

blender. A 5.0 g aliquot was placed in a pre-weighed Vycor crucible. The Vycor was then covered and placed in a muffle furnace at 200°C for 2 hours. The temperature was then raised to 550°C at the rate of 100°C/hour, and the sample left to ash overnight. The ash was cooled, dissolved three times in 1 ml nitric acid and heated almost to dryness, and then dissolved in 1 ml hydrochloric acid. The solution was then transferred to a 12 ml polypropylene tube and diluted to 10 ml with distilled, deionized water. The cadmium, copper and lead residues were determined by comparison with aqueous standards using a Perkin-Elmer model 5000 atomic absorption spectrophotometer. With the exception of using the Pb 217.0 NM line, the standard conditions as published by Perkin-Elmer (1976) were used. Recoveries from standard reference materials ranged from 91 to 95%. The lower limit of quantification was 0.1 ppm wet wt. based on a 5.0 g aliquot. This procedure was previously described by Haseltine et al. (1981). For mercury analysis, a different 1.25 g liver aliquot was placed in a 2-neck round-bottom flask. The aliquot was digested using the method described by Monk (1961). The determination was done by cold vapor atomic absorption spectrophotometry using the method of Hatch and Ott (1968) with a Coleman MAS-50B mercury analyzer. Recovery from National Bureau of Standards Reference Material [Albacore Tuna (*Thunnus alalunga*) RM 50] was 113%. The lower limit of reportable residues based on the aliquot size of 1.25 grams was 0.02 ppm wet wt. Another 0.5 g aliquot was placed into a 50 ml polypropylene tube for selenium and arsenic determinations. We followed procedures described by Krynitsky (1987). The mean (± SD) percent moisture of livers was 72.0 ± 1.6 and kidenys 74.8 ± 1.7, and if no moisture information was available for residues in the literature, these values were used to adjust wet weight concentrations to dry weight. The quantification limits adjusted to dry wt. were 0.35 ppm for selenium, aresnic, copper, and cadmium; and 0.07 ppm for mercury.

The carcasses were ground and homogenized in a food cutter. A 10 g aliquot was blended with sodium sulfate and extracted for 7 hours with hexane in a soxhlet apparatus. The extracts were cleaned up on a florisil column and the pesticides and PCBs were separated into three fractions by silica gel column chromatography. The analyses were done on a gas chromatograph equipped with Ni^{63} detector, automatic sampler, computing integrator and a 1.5/1.95% SP-2250/SP-2401 column. This procedure has been described in detail by Cromartie et al. (1975). The lower limit of quantification for pesticides (including *p, p'*-DDE, *p, p'*-DDT, dieldrin, heptachlor epoxide, oxychlordane, *cis*-chlordane, *trans*-nonachlor, *cis*-nonachlor, endrin, hexachlorobenzene, mirex) was 0.1 ppm wet wt. and 0.5 ppm for PCBs (as Aroclor 1260) and toxaphene. No residue concentrations were corrected on the basis of recovery data. We used one-half the detection limit for non-detections when calculating geometric means. If less than half of the samples contained no detectable residues, geometric means were not calculated. The level for statistical significance is $P = 0.05$, unless otherwise stated.

Results and Discussion

Migration

Spring migration of Western Grebes begins by the end of March and is initiated from the southern extreme of the winter range along the Pacific coast of Mexico, northward to British Columbia (Bent 1919; Palmer 1962). Initial movement is primarily to coastal staging areas. Western Grebes are transient during the move east; large inland lakes are used as staging points by up to 1000 birds at one time (Munro 1941; Palmer 1962). Grebes begin arriving on the breeding grounds by mid-April (Palmer 1962). Those birds reaching the extreme northeastern edge of the breeding range (southcentral Manitoba) arrive by the end of May. A few nonbreeders remain in Puget Sound and other coastal areas such as the Queen Charlotte Islands (0.8% of wintering population) (Vermeer et al. 1983). Many Western Grebes banded near the northeast edge of their breeding range (Delta Marsh, Manitoba) in the 1970s wintered (October-April) along the Pacific coast including 2 from coastal British Columbia, 13 from Washington (7 coastal and 6 Puget Sound), 1 from coastal Oregon, and 9 from coastal California (Nuecterlein, unpublished data). Clark's Grebes (*A. clarkii*) represent less than 1% of the breeding population of *Aechmophorus* in Canada (Storer 1965); their incidence progressively increases to the south in the United States (Ratti 1979; A.O.U. 1985). No Clark's Grebes were observed or collected in Puget Sound, therefore, we believe the origin of the Puget Sound wintering population is Canada and perhaps the northern United States.

Fall migration is variable, with southwestern movement towards the Pacific coast beginning as early as late August. Grebes start arriving at staging lakes in southern British Columbia by mid-September (Munro 1941; Palmer 1962). Most Western Grebes arrive at Vancouver Island and Puget Sound by mid-October with some flocks occasionally arriving earlier (Munro 1941; Palmer 1962).

Wintering Population

Western Grebes wintering at the head of Commencement Bay were the subject of this

TABLE 1. Bursa length (mm) and remige moult of Western Grebes collected early (17 October 1985) and late (6 February 1986) at Commencement Bay, Washington.

Bursa length (mm)	Male		Female	
	Early	Late	Early	Late
0	1	1		1
1-3				
4-6				
7-9				
10-12		1		
13-15				1
16-18			1(1)	
19-21			2	
22-24	4(4)[1]	4	4	1
25-27	2	2		4
28-30	1	1	4	2
31-32		1	1	1
Total	8	10	12	10

[1]Number in ( ) represents grebes with moulted remiges or remiges being replaced (in all cases flightless).

investigation (Figure 1). About 200 grebes were present on 17 October 1985, the date of the first collection. We counted 265 on 20 December 1985 in the same area, about 250 on 6 February 1986 during the final collection, and 210 on 8 May 1986. Many of the grebes during the last count were flapping their wings, possibly indicating a sign of premigratory restlessness. These counts plus those the following year, 8 October 1986 (65 grebes), 12 November 1986 (229 grebes), and 5 December 1986 (115 grebes), 9 February 1987 (160 grebes), 9 March 1987 (95 grebes) suggest that the collection area wintered about 200-250 grebes in 1985-1986, and slightly less in 1986-1987. We assume, based on the consistency of the counts, that the population overwintered in the collection area or immediately adjacent areas. At no time during field activities, including the collection period, were Western Grebes seen flying.

The bursa, which is maintained but progressively decreases in size through the first 1-1.5 years, is the best method to age Western Grebes (Storer and Nuechterlein 1985; Nuechterlein [in Storer and Jehl 1985]). Only 3 of our 40 grebes had no bursa; most possessed bursae >20 mm which implies they were in younger age classes (Table 1). However, the age structure of the collection may be biased because shooting from a boat may have been selective for younger birds. No birds flew when approached; all sought escape by diving and swimming. For the smaller Eared Grebe (*Podceps nigricollis*), most bursae regession took place late in the second winter (Storer and Jehl 1985); however, 3 post-breeding females had bursae measuring 12, 10 and 7 mm compared to juvenile averages of 15-21 mm in the autumn. Thus, the presence of bursae in Eared Grebes does not preclude breeding, and it probably is the same for Western Grebes.

Early work on moults of Western Grebes was summarized by Palmer (1962: 95). The Definitive Basic (adult winter) plumage is "acquired by complete Prebasic moult in the fall, the flight feathers shed simultaneously. A bird flightless in mid-winter, owing to moulting (remiges), was examined by J. Munro (W. E. Godfrey)." Sibley (1970) reported full wing moult in 35 of 300-400 oiled grebes examined (10%) in association with an oil spill in the Santa Barbara Channel on 28 January 1969 and 6 of 103 examined (6%) on 10 February 1969. None were aged. Freshly moulted or growing remiges were found in adult males taken 24 July to 18 October and in adult females taken 24 July to 4 September at an inland breeding location at Clear Lake, California (Storer and Neuchterlein 1985). Storer and Neuchterlein (1985) noted that some yearling (second year [SY]) Western Grebes begin the breeding season with fresh primaries, and they suggested a mid-winter remige moult for the age class.

The 20 Western Grebes collected on 17 October 1985 included 4 of 8 males and 1 of 12 females that were in remige moult or replacement (Table 1). The four males had 22-23 mm bursae and weighed 1544 to 1634 g (mean 1572). Two had moulted all remiges with no replacement started, but two had new remiges of 14 and 87 mm emerging. The female had lost all remiges with no replacements, had an 18 mm bursa and weighed 1171 g. The moulters all had above average weights for the respective sexes at the time (Table 2). In fact, the 4 males moulting averaged 1576 g, compared to 1484 g for the 4 not moulting. The moulting female was the fourth heaviest of 12. Those having moulted, especially the two with emerging remiges, were undoubtedly in Commencement Bay for more than a week or two. Based on their bursa length, we believe all moulters were in the same age class, perhaps 1½ year olds (SYs), because of some bursa regression from the maximum. In fact, the flightless birds may represent the few summering nonbreeders that were especially vulnerable to shooting.

Palmer (1962) lists 13 unsexed Western Grebes from Puget Sound with an average weight of 1477 g (range 795-1818). Our early males weighed significantly more than early females, but only females from Commencement Bay showed a significant weight gain from October to February (Table 2). The inclusion or exclusion of moulters did not change the findings. The mean weight reported by Palmer for Puget Sound was nearly

TABLE 2. Whole body weight, carcass weight, liver weight, and percent lipid in carcass of Western Grebes collected early (17 October 1985) and late (6 February 1986) at Commencement Bay, Washington.

Time and sex (n)	Whole body wt. (g) $\bar{X} \pm SD$	Carcass wt. (g) $\bar{X} \pm SD$	Liver wt. (g) $\bar{X} \pm SD$	Carcass Lipid (%) $\bar{X} \pm SD$
Includes All Grebes				
Early Male (8)	1530 ± 103B[1]	1071 ± 94BC	70.9 ± 9.3C	17.9 ± 4.0A
Early Female (12)	1108 ± 86A	749 ± 72A	45.0 ± 9.3A	14.0 ± 5.9A
Late Male (10)	1583 ± 194B	1171 ± 134C	66.2 ± 9.7BC	26.8 ± 4.7B
Late Female (10)	1406 ± 180B	1019 ± 127B	60.1 ± 6.5B	30.8 ± 7.3B
Early (20)	—	—	—	15.5 ± 5.5A
Late (20)	—	—	—	28.8 ± 6.3B
Excludes Moulting Grebes				
Early Male (4)	1490 ± 136B	1035 ± 121B	75.0 ± 4.7C	19.6 ± 3.7AB
Early Female (11)	1102 ± 88A	744 ± 72A	44.4 ± 9.5A	14.1 ± 6.2A
Late Male (10)	1583 ± 194B	1171 ± 134B	66.2 ± 9.7BC	26.8 ± 4.7BC
Late Female (10)	1406 ± 180B	1019 ± 127B	60.1 ± 6.5B	30.8 ± 7.3C
Early (15)	—	—	—	15.5 ± 6.0A
Late (20)	—	—	—	28.8 ± 6.3B

[1]Column sharing a letter in common, not significantly different (Tukey's Studentized Range Test). Data above solid line tested separately from data below solid line. Also, "early" and "late" combine sexes and were tested separately as well.

identical to the mean for both sexes combined in the February collection. Perhaps carcasses (feathers plucked, with the body cavity emptied and feet and bill removed) best represent weight and lipid changes over time. Females (with or without moulters) showed a significant increase in weight (36-37%), while the males showed a non-significant increase (9-13%). Actual lipid content (with and without moulters) increased in females from an average 104-105 g in October to 313 g in February, while in males it increased from 192-203 to 314 g.

Contaminant Changes During Winter

Based upon bursa characteristics, the three grebes without bursae were adults. A review of contaminant concentrations for the three compared to means for their sex-time group provided no evidence of higher residues (Figure 2). As mentioned earlier, we hypothesize that the flightless grebes collected in October represent the few nonbreeders that summer in Puget Sound — perhaps spending 1 continuous year in the vicinity of Commencement Bay (i.e., they could not have recently arrived, moulted and partially grown new remiges in a few days or weeks). To evaluate this hypothesis, we divided the grebes into three categories (early [15], late [20], and moulters from the early group [5]) and used a Jonckheere's procedure to test equality in residue burdens against ordered alternatives (Lehmann 1975). From bursa length and remige moult, we hypothesized that the three series represented grebes inhabiting Commencement Bay for < 1 month, about 4 months, and about 12 months. Therefore, contaminant burdens accumulated from the Bay were expected to be low, intermediate, and high. One-tailed probabilities for equality were rejected for most contaminants, therefore, the alternate hypothesis of ordered increases was accepted (Table 3). It is noteworthy that, the five flightless grebes contained the five highest PCB residues and five of the eight highest DDE residues. They also all contained above average mercury concentrations including the highest and third highest (7.9 and 4.0 ppm) and all contained above average concentrations of selenium including the three highest (24, 18, and 18 ppm).

In addition to the possibility that the moulting grebes spent a continuous year in Puget Sound, intrinsic seasonal changes associated with the moult could influence trace element concentrations in their livers. Osborn (1979a, 1979b) cautioned that the protein composition of animal tissues changes in ways which might effect the tissue sites to which metals may be bound. In livers of Starlings (*Sturnus vulgaris*), Osborn (1979b) reported seasonal variations in zinc, copper, iron, cadmium and mercury concentrations. The changes were associated with the nesting cycle or the moult. Osborn reported elevated cadmium (dry weight) but low mercury concentrations during the Starling moult, while copper during the moult was similar to that found during the fall and winter.

In summary, our analysis of residue concentrations (early *vs.* late) uses two approaches: (1) the

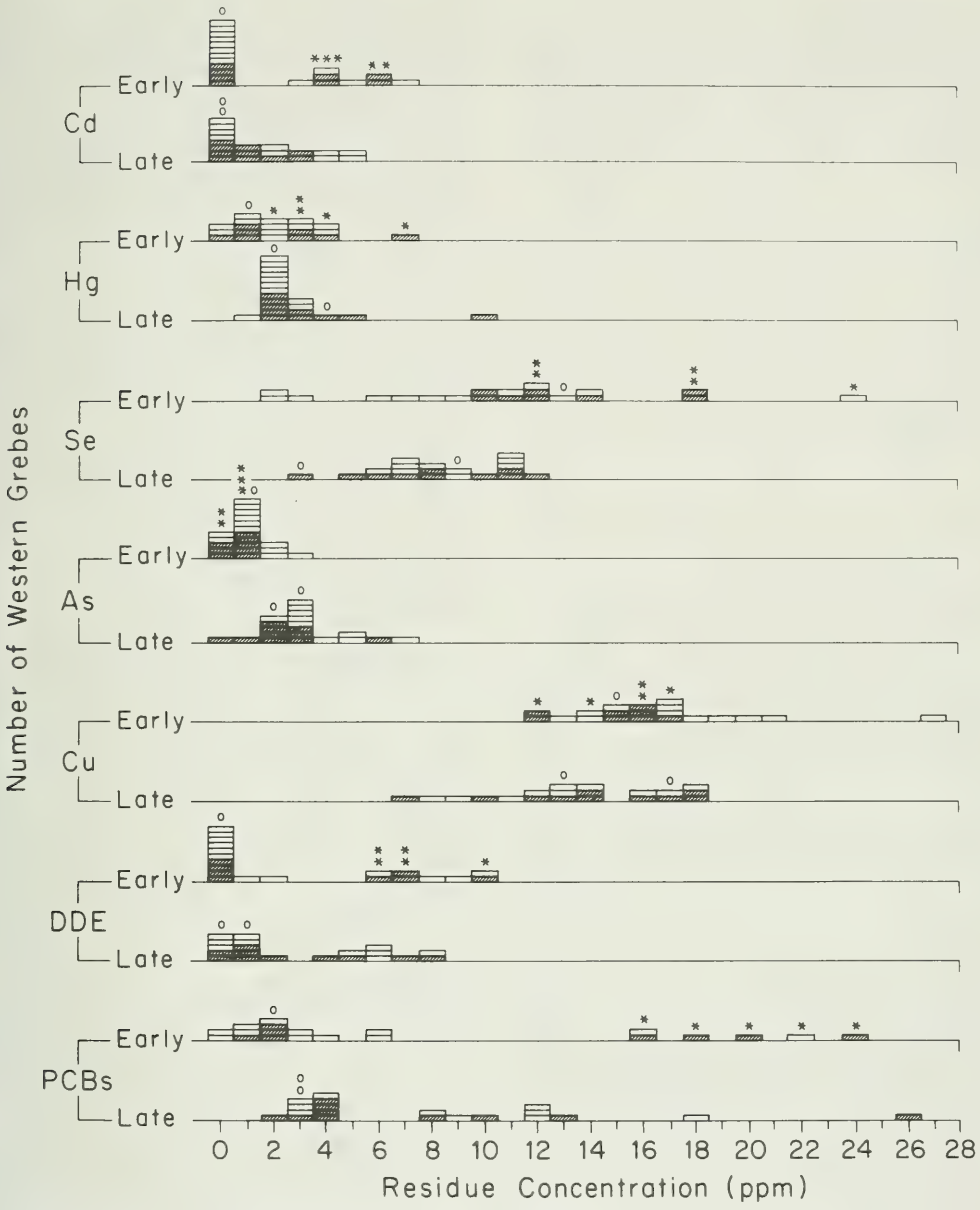

FIGURE 2. The frequency distribution of mercury, selenium, arsenic, and copper in the livers (ppm dry weight), cadmium in kidneys (ppm dry weight) and DDE and PCBs in carcasses (ppm wet weight) of Western Grebes collected in Commmencement Bay, Puget Sound, Washington (* = moult, o = no bursa, dark = male, light = female).

inclusion of all data, and (2) the exclusion of those moulting and suspected of spending a continuous year near Commencement Bay. We cannot be certain about either the length of stay of the moulters in the Commencement Bay vicinity, or intrinsic changes in residue concentrations associated with the remige moult, therefore, we believe the data set without the moulters provides the most meaningful information on contaminant accumulation during the winter.

Elements in Liver and Kidney

No significant sex related differences in concentrations were detected for any of the elements tested (selenium, mercury, arsenic,

TABLE 3. Jonckheere test statistics for the null hypothesis of no difference in contaminant concentrations from early to late to moulters *vs.* an ordered increase.

Contaminant	Test Statistic (V)	Probability (P)
PCB's	4.48	< 0.0001
DDE	3.50	0.0002
Mercury	2.96	0.0015
DDD	2.57	0.0051
Chlordanes[1]	2.55	0.0054
Cadmium	2.11	0.0174
Arsenic	1.56	0.0594
Selenium	1.50	0.0668
Copper	-1.87	0.9693

[1]Chlordanes include: oxychlordane, *cis*-chlordane, *trans*-nonachlor, and *cis*-nonachlor.

copper or cadmium) in either the early or the late collection period (Table 4).

Selenium. No significant change (with or without the moulters) in selenium concentrations was detected from the early (9.3 or 7.6 ppm) to the late (7.9 ppm) collection period. Selenium concentrations showed the widest range (2.2 to 24 ppm, dry weight) of any element detected in the early collection, but residue extremes were reduced by about half over the winter (3.1 to 12 ppm) (Figure 1). The highest concentrations were among the five moulters which probably summered in the area (16.3 ppm, range 12.4 to 24.2). The moulters provided the only evidence for possible selenium accumulation in Commencement Bay.

Seleniferous rock exists throughout major portions of the Western Grebe breeding range in Montana, North Dakota, southern Saskatchewan and Manitoba (Rosenfeld and Beath 1964). It appears that the selenium burden in the Western Grebe was obtained on the breeding grounds before arrival at Commencement Bay. Gahler et al. (1982) reported low selenium (< 0.20 ppm wet weight) concentrations in fish muscle from all stations sampled in Commencement Bay in 1981-1982.

Much higher concentrations of selenium were reported in livers of Surf Scoters (*Melanitta perspicillata*) and Greater Scaup (*Aythya marila*) from San Francisco Bay in March-April 1982 (34.4 and 19.3 ppm, geometric mean, dry weight), respectively (Ohlendorf et al. 1986a). Another series of Surf Scoters from San Francisco Bay (January and March 1985) contained even higher selenium concentrations (57.9 and 61.6 ppm, respectively) (Ohlendorf et al. 1988).

Mercury. Concentrations of mercury increased significantly between the early (1.5 ppm) and the late (2.5 ppm) collection periods when moulters were excluded (Table 4). Perhaps the above-average concentrations (3.6 ppm, range 2.2 to 7.9) in moulters provides evidence that they spent additional time at Puget Sound, which is mercury enriched (Bloom and Crecelius 1987). Osborn (1979b) did not show increased mercury concentrations in Starling livers during the moult. Therefore, resident species would be expected to show higher accumulations and, livers of adult Great Blue Herons (a resident species) from Commencement Bay contained 11.7 to 16.4 ppm

TABLE 4. Geometric mean residues (ppm dry weight) of selenium, mercury, arsenic and copper in livers and cadmium in kidneys of Western Grebes collected early (17 October 1985) and late (6 February 1986) at Commencement Bay, Washington.

Time and Sex (n)	Selenium	Mercury	Arsenic	Copper	Cadmium
Includes All Grebes					
Early Male (8)	12.76 A[1]	2.07 A	0.79 A	14.83 AB	0.98 A
Early Female (12)	7.45 A	1.79 A	1.09 AB	17.30 B	0.56 A
Late Male (10)	7.50 A	2.96 A	2.00 BC	13.55 AB	0.76 A
Late Female (10)	8.30 A	2.07 A	3.65 C	12.74 A	0.94 A
Early (20)	9.25 A	1.90 A	0.96 A	16.26 B	0.70 A
Late (20)	7.89 A	2.48 A	2.70 B	13.15 A	0.85 A
Excludes Moulting Grebes					
Early Male (4)	11.02 A	1.06 A	1.07 A	14.45 A	0.20 A
Early Female (11)	6.70 A	1.77 AB	1.11 A	17.62 A	0.47 A
Late Male (10)	7.50 A	2.96 B	2.00 AB	13.55 A	0.76 A
Late Female (10)	8.30 A	2.07 AB	3.65 B	12.74 A	0.94 A
Early (15)	7.64 A	1.54 A	1.10 A	16.71 B	0.38 A
Late (20)	7.89 A	2.48 B	2.70 B	13.15 A	0.85 A

[1]Columns sharing a letter in common, not significantly different (Tukey's Studentized Range Test). Data above solid line tested separately from data below solid line. Also, "early" and "late" combine sexes and were tested separately as well.

mercury (dry weight) (Riley et al. 1983). The frequency distribution of mercury concentrations provides more evidence that increases were real. Eight of 20 grebes contained less than 1.5 ppm mercury during the early collection period, while only 1 of 20 contained less than 1.5 ppm in the late collection period (Figure 2).

Industrial preparation of chlorine is a probable source of mercury contamination in Puget Sound, together with the pulp and paper industry which used mercury as a slimicide until the early 1970s (Fimreite et al. 1971; Eisler 1987). Effluent discharge of contaminated waste has increased mercury sediment concentrations in Puget Sound. In 1979, the sediment concentration of mercury from Commencement Bay (Site 15, see Figure 1). was 1.7 times as great (0.15 ppm) as those samples taken south of Whidbey Island (mean 0.09 ppm) and 3.0 times as great as the pre-anthropogenic mercury concentration of about 0.05 ppm (1848-1878) (Bloom and Crecelius 1987). Peak mercury contaminant discharge occurred during the 1950s and 1960s. The significant increase of mercury concentrations in Western Grebes between early and late collections at Commencement Bay indicates that accumulation was still occurring. Mercury concentrations in muscle from Commencement Bay fish were generally less than 0.10 ppm (wet weight) (Gahler et al. 1982). At all stations where comparisons could be made, the "mixed" fish and the "off-bottom" fish contained higher average mercury concentrations than the "bottom" fish.

Arsenic. Significant increases in arsenic concentrations from the early (0.96 or 1.1 ppm) to the late (2.7 ppm) collection period was found with or without the moulters (Table 4). The frequency distribution of residue concentrations, as evaluated for mercury, showed 16 of 20 early grebes and only 2 of 20 late grebes with less than 1.5 ppm arsenic (Figure 2).

Almost all (97%) of the arsenic made worldwide enters end-product manufacture in the form of arsenic trioxide (As_2O_3), and the sole producer and refiner of As_2O_3 in the U.S. was a copper smelter in Tacoma, Washington (N.A.S. 1977), near our study area until its closure in early 1985. Arsenic in Puget Sound sediments, where smelter contamination was not a factor, varied from 3.2 to 15 ppm (dry weight). Near the Tacoma smelter, sediments contained up to 10 000 ppm (Crecelius et al. 1975). Arsenic concentrations in sediments 8-16 km away were 2-3 times background levels (Crecelius and Carpenter 1973). The smelter released about 300 tons/year arsenic in stack dust to the atmosphere and roughly an equal amount in liquid effluent directly into Puget Sound. The smelter also dumped solid slag containing 1% arsenic directly into Puget Sound and crushed slag was used as sandblasting material in shipyards and as roadbed gravel in log-loading yards which subsequently ran off or leached into the Bay. The smelter dust, which was wind transported over 45 km also contributed arsenic to lakes and soils (Crecelius and Carpenter 1973).

Arsenic is bioconcentrated by aquatic organisms but not biomagnified. Plants usually accumulate more than fish with crustaceans accumulating intermediate amounts (Woolson 1975a). Gahler et al. (1982) reported arsenic in fish muscle from all stations sampled in Commencement Bay in 1981-1982. The highest mean concentrations (8.6 and 16.2 ppm wet weight) were in bottom fish (English Sole, *Parophrys vetulus*, and Rock Sole, *Lepidopsetta bilineata*) caught near Point Defiance dock — the collection site nearest the copper smelter. Arsenic in fish at other sites was variable with most means in the 0.75 to 5.0 ppm range. Organically-bound arsenic in flesh evidently has low toxicity (Ferguson and Gavis 1972). In fact, Penrose et al. (1975) thought arsenic may be overrated as a potential pollutant because marine animals, at least, seem to possess the potential to deal with this element by converting the moderately toxic inorganic form to an organic derivative that is biologically and chemically stable and probably nontoxic. Although arsenic increased significantly in Western Grebe livers from the early to late collection period, the biological impact of that increase (1.1 to 2.7 ppm), based on the above discussion, was probably not important.

Wintering shorebirds near Corpus Christi, Texas, contained lower arsenic concentrations in their livers that ranged from 0.18 to 0.82 ppm (geometric mean, dry weight) with a maximum of 5.4 ppm in an individual (White et al. 1980). The authors thought the low concentrations reflected background contamination. The meager liver residue data available (*see* Eisler 1988) were in the same range except an Osprey (*Pandion haliaetus*) from Chesepeake Bay that died with 60 ppm arsenic (dry weight) (Wiemeyer et al. 1980). Eisler (1988) concluded that arsenicals are readily absorbed after ingestion with most being rapidly excreted in the urine during the first few days, or at most a week.

Copper. Mean copper concentrations decreased significantly from the early (16.3 or 16.7 ppm) to the late (13.2 ppm) collection period with or without moulters (Table 4). The frequency distribution of residue concentrations shows a general shift downward with higher extremes in the early period. The moulters provided no hint of increased copper concentrations (15.0 ppm, range 12.0 to 17.1) (Figure 2).

TABLE 5. Geometric mean residues (ppm wet weight) of organochlorine pesticides and PCB's in carcasses of Western Grebes collected early (17 October 1985) and late (6 February 1986) at Commencement Bay, Washington.

Time and Sex (n)	DDE	DDD	PCBs	Chlordanes[1]
Includes All Grebes				
Early Male (8)	1.01 A[2]	0.12 A	5.69 A	0.15 A
Early Female (12)	0.83 A	0.16 A	2.48 A	0.13 A
Late Male (10)	1.67 A	0.24 A	5.78 A	0.19 A
Late Female (10)	1.87 A	0.23 A	7.01 A	0.24 A
Early (20)	0.90 A	0.14 A	3.47 A	0.13 A
Late (20)	1.77 A	0.24 A	6.37 A	0.21 A
Excludes Moulting Grebes				
Early Male (4)	0.14 A	0.05 A	1.68 A	0.05 A
Early Female (11)	0.69 AB	0.16 A	2.04 AB	0.12 A
Late Male (10)	1.67 B	0.24 A	5.78 AB	0.19 A
Late Female (10)	1.87 B	0.23 A	7.01 B	0.24 A
Early (15)	0.45 A	0.12 A	1.94 A	0.10 A
Late (20)	1.77 B	0.24 A	6.37 B	0.21 B

[1]Chlordanes include: oxychlordane, *cis*-chlordane, *trans*-nonachlor, and *cis*-nonachlor.

[2]Columns sharing a letter in common, not significantly different (Tukey's Studentized Range Test). Data above solid line tested separately from data below solid line. Also, "early" and "late" combine sexes and were tested separately as well.

Sediment concentrations of copper increased significantly since the 1890 start-up of a copper smelter (Bloom and Crecelius 1987). Smokestack emissions from the smelter contained 460 metric tons per year of copper (Crecelius et al. 1975). Mean pre-1890 copper concentrations in sediment were below 35 ppm (dry weight), with 42.6 ppm in Commencement Bay from the 1979 layer (Bloom and Crecelius 1987). The fish from the collection site nearest the smelter contained the highest copper concentrations (up to 0.89 ppm, wet wt.); and, other fish samples averaged from 0.30 to 0.50 ppm (Gahler et al. 1982). Reports of large copper deposits at the eastern edge of the Western Grebe breeding range in Canada (Nriagu 1979) may account for the deficit (loss) while on the Commencement Bay wintering grounds.

Cadmium. Kidney concentrations of cadmium increased but not significantly from the early (0.70 or 0.38 ppm) to the late (0.85 ppm) collection period with or without the moulters (Table 4). Cadmium was not detected in 19 of the grebes (4 early males, 8 early females, 3 late males, and 4 late females). The five moulters all contained elevated cadmium concentrations (mean 4.6 ppm, range 3.5 to 6.3). The late collection included only 3 birds above 3.5 ppm.

No increase in sediment layer concentrations of cadmium was noted in Puget Sound from 1890 to 1979, with the concentrations remaining fairly constant at below 0.5 ppm (dry weight) (Bloom and Crecelius 1987). Concentrations of cadmium in fish muscle were low for all sampling stations in Commencement Bay, usually below 0.01 ppm (wet weight) (Gahler et al. 1982). The general shift in the frequency distribution of cadmium in kidneys from early to late suggests that a real increase occurred on the wintering grounds. The elevated concentrations in the moulters could perhaps be a result of the moult itself since Osborn (1979b) reported elevated concentrations in Starling livers during the moult.

Lead. We detected lead infrequently in livers (4 of 40 samples) with no pattern apparent. Grebes containing lead included 1 of 5 moulters (1.5 ppm), 2 of 15 early birds (0.42 and 2.2 ppm), and 1 of 20 late birds (0.77 ppm).

Concentrations of lead in sediment layers of Puget Sound increased since 1890 when the copper smelter was established. Pre-1890 sediment layers contained < 10 ppm lead (dry weight), while the 1979 sediment layer from Commencement Bay contained 18.3 ppm (dry weight) (Bloom and Crecelius 1987). The smelter smokestack emitted about 2800 metric tons of lead per year (Crecelius et al. 1975). Emissions from motorized vehicles are still a source of lead contamination. Lead residues were highest in fish caught nearest the smelter with the other samples from Commencement Bay usually averaging 0.35 to 0.55 ppm (wet weight) (Gahler et al. 1982). Although lead was prevalent in the sediment and found in the edible parts of fish, no lead accumulation in grebe livers was detected.

Organochlorines in carcass

The lipophilic organochlorine pesticides and PCBs were analysed from plucked carcasses (Table 5); there was a significant increase in lipid content

from the early to the late collection period (Table 2). No sex-related differences in residues were detected for any of the organochlorines tested in either the early or the late collecting period (Table 4).

DDE. We found that DDE increased significantly in Western Grebes from the early (0.45 ppm) to the late (1.8 ppm) collecting period and the moulters contained even higher (7.0 ppm) concentrations (Table 5). DDD increased (0.12 to 0.24 ppm) but not significantly, and no DDT was detected. Residues varied widely with half of the early collection (4 of 8 males and 6 of 12 females) containing less than 0.50 ppm DDE, and with 5 of the 8 highest residues from moulters (Figure 2).

DDTr (DDT, DDD, DDE) concentrations in sediment near the grebe collection site were extremely low (0.01 ppm) (Table 6); the only organochlorine pesticides detected in muscle tissue of fish from Commencement Bay were DDE, DDD, and DDT (Gahler et al. 1982). The DDTr concentrations in fish ranged from < 0.001 ppm (wet weight) to 0.06 ppm and were much lower than PCBs, with the highest average concentrations measured from the Hylebos Waterway. However, the relatively low DDTr concentrations in fish resulted in an increase of DDE residues in Western Grebes.

Chlordanes and Hexachlorobenzene. When moulters were excluded, chlordanes increased significantly from early (0.10 ppm) to late (0.21 ppm) (Table 5). *Trans*-nonachlor was the form most frequently encountered, followed by *cis*-nonachlor, *cis*-chlordane, and oxychlordane. HCB was detected (0.12 ppm) in one female from the early collection (a moulter), and in 2 males and 2 females from the late collection (0.10, 0.12, 0.16, and 0.16 ppm). Chlordane was not detected in fish samples from Commencement Bay, but HCB occurred in fish taken from the Hylebos Waterway and ranged from 0.01 to 0.15 ppm wet weight (Gahler et al. 1982). HCB was also found in 59 of 61 sediment samples taken in Puget Sound; concentrations ranged from 0.02 to 1300 ppb (dry weight) but did not exceed 2 ppb for samples taken outside Commencement Bay (Malins et al. 1980). The occurrence of HCB in Commencement Bay fish and sediment supports the contention that HCB was accumulated by grebes during the winter.

PCBs. The PCB concentrations paralleled DDE and showed a significant increase from the early (1.9 ppm) to the late (6.4 ppm) collection when the moulters were excluded (Table 5). Five of the six highest early concentrations were from moulters (mean 19.8 ppm, range 16 to 24 ppm), the other concentrations were considerably lower.

PCBs in sediment near the grebe collection site averaged 0.80 ppm compared to 0.01 for DDTr (Table 6). The highest average PCB concentrations (0.55 and 0.62 ppm, wet weight) in fish muscle were found in "bottom" and "mixed" fish, respectively, from the Hylebos Waterway (Gahler et al. 1982). The PCB concentrations in fish muscle were about 10 times higher than DDTr and, as expected, PCB accumulation in Western Grebes was much higher than DDTr during the winter.

Others. Dieldrin was detected in 2 grebes (non-moulters) in the early collection and none in the

TABLE 6. A comparison of sediment, fish, and Western Grebe pollutant concentrations (ppm).

Element or Compound	Sediment (dry weight)			Fish Muscle[d] (wet weight)	Western Grebe[e]	
	Grebe Site[a]	Center of Bay[b]	Puget Sound[c]		Early	Late
Selenium	ND	ND	ND	< 0.20	7.6	7.9
Arsenic	5.5	13.6	ND	0.75-5.0	1.1	2.7
Cadmium	0.45	ND	[f]	0.01	0.38	0.85
Lead	20	18.3	30.1	0.35-0.55	[g]	[g]
Copper	52	42.6	40.6	0.30-0.50	16.7	13.2
Mercury	1.1	0.15	0.19	< 0.10	1.5	2.5
DDTr	0.01	ND	ND	0.002-0.009	0.45	1.8
PCBs	0.80	ND	ND	0.03-0.19	1.9	6.4

ND = Not Determined

[a]From Weitkamp et al. (1987) for the years 1985-1986. Mean of 5 sampling stations beginning at the mouth of St. Paul Waterway and extending 300 m into Commencement Bay.

[b]Commencement Bay Site 15 in 1979; about 4 to 5 km from grebe collection site (Bloom and Crecelius 1987). For arsenic, mean of 4 samples taken in 1970-1972 near Site 15 (Crecelius et al. 1975).

[c]Mean for 21 sites throughout Puget Sound in 1979 (Bloom and Crecelius 1987).

[d]From Gahler et al. (1982) for Commencement Bay in 1981-1982.

[e]This study, DDE and PCBs in carcass (wet weight), cadmium in kidney and all other elements in liver (dry weight).

[f]Only 6 of 21 samples (high of 0.42 ppm) were above detection limit of 0.25 ppm.

[g]Detected infrequently, geometric means not calculated.

late collection; heptachlor epoxide, endrin, and toxaphene were not detected during the study.

Concluding Remarks

Western Grebes nesting in Canada and perhaps the northern United States accumulated mercury, arsenic, DDE, PCBs, chlordanes, and perhaps cadmium during a relatively short time in Commencement Bay. Selenium was probably not accumulated in Commencement Bay, but the high levels in the moulters remains an enigma (perhaps related to the moult itself); copper was actually lost by the grebes and no pattern was apparent for lead. However, it is also important to recognize that the accumulation we documented occurred from 17 October 1985 to 6 February 1986 (112 days), but the Western Grebes were still in Commencement Bay on 8 May 1986 (3 months later) and were likely to accumulate higher levels. Puget Sound sediments have been significantly enriched with lead and mercury, slightly enriched in copper, but with no change in cadmium since the 1890s (Bloom and Crecelius 1987). Trying to directly relate grebe contaminant concentrations to sediment or fish concentrations was not the main objective of this paper, although we present some of the basic information.

The concentrations of elements and compounds detected in the Western Grebes seemed to be of little toxicological significance; however, our method of study through collections precluded determination of sublethal effects. Our grebes were in good body condition; overwintering birds accumulated heavy stores of fat by the February collections. These findings are somewhat paradoxical in that Commencement Bay is one of the most heavily polluted sites in Puget Sound; certain fish collected in the area tend to have high pollutant burdens and to develop hepatic lesions (Becker et al. 1987; Malins et al. 1984). Our cursory examination revealed no unusual problems with the reproductive system of grebes; Fry et al. (1987) reported abnormal development of right oviducts in Glaucus-winged Gulls (*Larus occidentalis*) from Puget Sound. They also reported slight eggshell thinning and supernormal clutches in these gulls; all of these problems were suspected of being related to pollution.

Leonzio et al. (1986) studied Eared Grebes in coastal Italy in a manner similar to our approach. During the multi-year investigation, grebe livers rapidly accumulated mercury (September-October means 9.4 to 16.6 ppm dry weight *vs.* April 42.4 to 57.9), but not nearly as much selenium (10.4 to 10.5 *vs.* 14.1 to 16.3). It is noteworthy that the late collections in Italy contained much higher concentrations of both mercury (20 ×) and selenium (1.9 ×) than we found in our Western Grebes in February.

Concentrations of elements and compounds in Western Grebes were all below levels known to induce mortality or sublethal effects; however, critical levels of arsenic, and even selenium, in tissues is poorly known. This is confounded by combined effects of certain elements; for example, arsenic and selenium may be either antagonistic or synergistic depending upon the elemental compounds involved (N.R.C.C. 1978). Arsenic concentrations in Western Grebe livers were well below the no-effect level (7.5 ppm, wet weight) in livers of experimental Northern Bobwhite (*Colinus virginianus*) given dietary levels of several arsenical pesticides (Woolson 1975b). Selenium concentrations in livers of experimental birds vary widely depending upon the form of compound administered (Heinz et al. 1987). Mallards (*Anas platyrhyncos*) fed diets of 1 and 2 ppm (dry weight) selenium (selenomethionine) showed no adverse reproductive effects and laid eggs containing 0.8 and 1.6 ppm selenium (wet weight), or 2.4 and 4.8 (dry weight) (Hoffman and Heinz 1988). Ohlendorf et al. (1986b) reported adverse selenium effects on reproduction began at about 10 ppm (dry weight) in the egg, or perhaps a little lower. The muscle of fish in Commencement Bay contained levels of selenium below 1 or 2 ppm (dry weight), i.e., < 0.20 ppm wet weight. Mercury concentrations in livers of our grebes were well below those known to be lethal in experimental birds (summary by Eisler 1987); this same conclusion seemed to hold for lead (summary by Eisler 1988) and cadmium (White and Finley 1978). Copper concentrations were in the range considered normal for most birds (Mebring et al. 1960). Although the grebes accumulated DDTr and PCBs from the early to the late periods, carcass residues were low in comparison to those of experimental birds surviving extremely high dietary levels of PCBs (Stickel et al. 1984) or DDE (Stickel et al. 1970).

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Notes

Observation of an Arctic Ground Squirrel, *Spermophilus p. parryi*, — Short-tailed Weasel, *Mustela erminea*, Interaction

MARK R. SIMPSON

Department of Biology, York University, North York, Ontario M3J 1P3

Simpson, Mark, R. 1990. Observation of an Arctic Ground Squirrel, *Spermophilus p. parryi*, Short-tailed Weasel, *Mustela erminea,* interaction. Canadian Field-Naturalist 104(3): 473–474.

An adult male Arctic Ground Squirrel successfully chased a Long-tailed Weasel from the vicinity of the squirrel's burrow, 7 km north of Eskimo Point, Northwest Territories. Despite an increase in size in the northern part of its range, the Short-tailed Weasel may be still too small to prey on ground squirrels other than unprotected juveniles.

Key Words: Arctic Ground Squirrel, *Spermophilus parryi*, Short-tailed Weasel,, *Mustela erminea*, predation, aggression.

Ground squirrels (*Spermophilus* spp.) are known to be an important food item in the diet of the Longtailed Weasel (*Mustela frenata*; Errington 1936; Quick 1951). They are also believed to be occasional prey of the Short-tailed Weasel (*Mustela erminea*; Banfield 1974; Aldous and Manweiler 1942; Hamilton 1933; J. O. Murie, personal communication). However, Simms (1979) argued that the appearance of tissue and hair from larger prey (e.g. squirrels and lagomorphs) in Short-tailed Weasel fecal samples was a result of scavenging, rather than predation by the weasel which is limited by its small size. However, body size in Short-tailed Weasels increases at latitudes above 55° N latitude, such that weasels in northern areas should be able to kill larger prey (McNab 1971). Data on the food habits of northern Short-tailed Weasels are limited to those of Simms (1978) on Igloolik Island, Northern Territories, where weasels and ground squirrels were not sympatric at the time of the study (D. M. Cameron, personal communication). Therefore, it is still unclear whether Short-tailed Weasels are able to prey upon Arctic Ground Squirrels, *Spermophilus parryi.* My observation suggests that Short-tailed Weasels may not successfully prey on Arctic Ground Squirrels. To date, there are no published accounts of behavioural interactions between Arctic Ground Squirrels and Short-tailed Weasels.

An aggressive interaction between an Arctic Ground Squirrel (*S. p. parryi*) and a Short-tailed Weasel was observed 2 July 1988 on an esker 7 km north of Eskimo Point, Northwest Territories (61°06′N; 93°59′W). While observing the behaviour of a 825 g male ground squirrel in the vicinity of its burrow, I detected a weasel approximately 100 m away. The squirrel appeared to be unaware of the approaching weasel and continued to alternate between digging and grooming at one of its burrow entrances. When the weasel had approached to within 25 m of the burrow, the ground squirrel assumed a tall-scanning, "picket-pin" position (ie. standing on hind legs, with front legs folded against its abdomen) and emitted a series of four "warning calls". By this time, the weasel was within 2 m of a burrow entrance, 4 m from the entrance at which the squirrel was located. The squirrel abandoned the erect position and aggressively chased the weasel from the burrow. The case continued for 3.5 min. with the weasel leading the squirrel by approximately 0.25 m, although at no time did the squirrel come in contact with the weasel. The chase ended when the weasel took refuge within thick willows (*Salix* sp.). The ground squirrel then mounted a rock within 2 m of the chase termination point, 40m from his burrow, and again assumed a scanning position which it held for 5 min. before returning to, and entering, its burrow. The ground squirrel was the sole inhabitant of that burrow, the closest resident squirrel being 266 m away.

Simms (1979) stated that the size of Short-tailed Weasels limits their ability to prey upon large prey, such as adult Arctic Ground Squirrels. My observation lends support to Simms' hypothesis, but predation upon unprotected juveniles, for which the weasel may have been searching, could be more successful. J. O. Murie (personal communication) suspects that predation by Short-tailed Weasels may explain the loss of several litters in the Columbian Ground Squirrel

(*Spermophilus columbianus*) at his field site in southern Alberta, and he has observed adult ground squirrels vigorously chasing Long-tailed Weasels while young ground squirrels were underground.

These anecdotal observations suggested that successful predation by the larger northern races of Short-tailed Weasels on large prey such as Arctic Ground Squirrels is limited to attacks upon juvenile squirrels. Confirmation of this conclusion would require a detailed seasonal analysis of Short-tailed Weasel food habits in areas where the weasel and ground squirrel are sympatric.

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A Mixed Wood Duck, *Aix sponsa*, — Mallard, *Anas platyrhynchos*, Clutch

STEVEN F. WILSON[1]

Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia V5A 1S6
[1]Present address: Creston Valley Wildlife Management Area, Box 640, Creston, British Columbia V0B 1G0

Wilson, Steven F. 1990. A mixed Wood Duck, *Aix sponsa*, — Mallard, *Anas platyrhynchos*, clutch. Canadian Field-Naturalist 104(3): 474–475.

A female Mallard (*Anas platyrhynchos*) was flushed from a nest in a large Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*) tree near Creston, British Columbia. The nest contained five Mallard eggs and one Wood Duck (*Aix sponsa*) egg. The female deserted soon after the nest was discovered.

Key Words: Mallard, *Anas platyrhynchos*, Wood Duck, *Aix sponsa*, brood parasitism, British Columbia.

Female Wood Ducks (*Aix sponsa*) frequently lay eggs in the nests of conspecifics (Semel and Sherman 1986; Heusmann et al. 1980; Clawson et al. 1979; Morse and Wight 1969) and, occasionally, in the nests of other cavity-nesting species such as Hooded Mergansers (*Lophodytes cucculatus*, Bellrose 1976). Ground-nesting Mallards (*Anas platyrhynchos*) are parasitized by a number of waterfowl species including the Redhead (*Aythya americana*), Ruddy Duck (*Oxyura jamaicensis*), Northern Pintail (*Anas acuta*), Cinnamon Teal (*A. cyanoptera*), Northern Shoveler (*A. clypeata*), and by other Mallards (Weller 1959). This note reports on a nest containing a clutch of Wood Duck and Mallard eggs.

While examining tree cavities for Wood Duck nests on the Creston Valley Wildlife Management Area (CVWMA) near Creston, British Columbia (49° 05′ N, 116° 35′ W) on 13 May 1988, I found a nest containing five Mallard eggs and one Wood Duck egg. The nest was in a live Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*) tree (173 cm dbh) on the edge of a 249 ha managed marsh unit. The nest was located 4 m above the ground in a bucket cavity 38 cm deep. A Mallard female flushed from the nest while I was climbing the tree. The eggs were warm and the base of the cavity was lined with a large volume of Mallard down. The eggs of both species were easily distinguished by their colour and size. The Mallard eggs were greenish buff and measured 57.6 mm (SD = 1.0) × 41.8 mm (SD = 0.4). The Wood Duck egg was dull white and measured 51.4 mm × 39.4 mm. I checked the nest again on 16 May but it was abandoned and all eggs, and egg remains, were gone.

As there was no litter in the bottom of the nest cavity, and Wood Ducks rarely nest in situations where eggs cannot be covered with material during early laying (Grice and Rogers 1965), and as Wood Ducks that dump eggs, with no intention of incubating them, rarely do so in cavities without active nests (Heusmann et al. 1980), I suggest that in this case the Wood Duck laid in an active Mallard nest.

Both Mallards and Wood Ducks are common on the management area. Butler et al. (1986) estimated the breeding population of Mallards and Wood Ducks on the CVWMA (7000 ha in total) to be 244 and 120 pairs, respectively (1980 data). I did not find any other tree-nesting Mallards in 1988, despite 166 empty nest boxes and abundant natural cavities. Prior to my study, Mallards had been reported nesting in trees only twice in 10 years of nest surveys on the CVWMA (B. Stushnoff, personal communication).

Mallards that nest in hollow tree trunks, tree crotches (Bellrose 1976), or in man-made nesting structures such as elevated baskets or nest boxes (Bishop and Barratt 1970) risk being parasitized by cavity-nesting waterfowl. Titman and Lowther (1971) found Common Goldeneyes (*Bucephala clangula*) parasitizing box-nesting Mallards in Manitoba; however, Mallards were poor hosts for the goldeneye eggs as no parasitic eggs hatched, perhaps due to the shorter incubation period of Mallard eggs. The incubation period of Wood Duck eggs is also longer than that of Mallard eggs (Bellrose 1976).

Wood Duck females that lay parasitically detect suitable hosts by observing the activity of breeding pairs around nest sites (Semel and Sherman 1986). As Mallards nest in trees only rarely, Wood Ducks may not distinguish them from more suitable hosts.

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On the Longevity of a Deer Mouse, *Peromyscus maniculatus*: A Canadian Record

HANK DAVIS

Davis, Hank. 1990. On the longevity of a Deer Mouse, *Peromyscus maniculatus*: A Canadian record. Canadian Field-Naturalist 104(3): 476.

Virtually no data exist to support the oft-repeated claim that *Peromyscus maniculatus* may live to eight years. I report what I believe is the longest-lived Deer Mouse recorded in Canada, a male aged approximately six years, one month.

Key Words: *Peromyscus maniculatus*, Deer Mouse, longevity, Ontario, Canada.

Despite the great number of studies done on the Deer Mouse, *Peromyscus maniculatus*, both in the laboratory and in the field, relatively little is known about longevity in this species. A single report based on animals in a laboratory (Dice, 1933) appears to be the source of the oft-repeated claim that this species may live as long as eight years (Banfield 1974; Burt 1957; King 1968).

This paucity of information is understandable. As King (1968) noted, 99% of *Peromyscus maniculatus* live less than a year. Writing about its close relative, the White-footed Mouse, *Peromyscus leucopus*, Banfield (1974) stated that it is unlikely that any individual lives long enough in the wild to die of old age.

Observations on longevity of laboratory specimens are probably not indicative of potential lifespan since *Peromyscus maniculatus* tend to be used in studies of behavior, rather than aging, and thus may not be kept long enough to achieve their maximum lifespans in captivity. The lack of information on longevity in *Peromyscus maniculatus* makes any observation on individual lifespans valuable.

The brief report by Dice (1933) recorded the lifespans of several animals that were descended from individuals live-trapped in Michigan in 1923. The age distribution of these animals was bimodal, with a mean that can be estimated at just over 3 years. The oldest female lived to 5 years, 3 months. The oldest male was 8 years, 4 months. It is the age of this latter individual that has frequently been quoted as the definitive statement of the species' longevity.

I have kept an individual *Peromyscus maniculatus* in captivity for virtually its entire lifespan. On 6 August 1982, I live-trapped a male in Puslinch Township, Wellington County, in southern Ontario that was judged to be approximately one month old. "Ruby", as he was called, was kept as a pet until his death on 23 July 1988, early in his seventh year. The animal was housed in a 100 litre glass aquarium with an exercise wheel, wood chip bedding, and ample cloth and paper nesting material. Food consisted of commercial rat chow, supplemented with nuts and fruit, and a supply of meal worms. Ruby remained slim and active for the majority of his life, and did not undergo the progressive reduction in activity level described for individuals of the related *P. leucopus* (Anonymous 1981). In addition, Ruby showed none of the signs of "senility" described by Dice (1933), which include "stiffness of movement and lack of vigor," as well as "thin pelage — paler in color than normal for animals in their prime." Ruby did suffer a noticeable loss of weight, as reported by Dice, but this only occurred two weeks immediately prior to death.

This individual represents the oldest Deer Mouse yet reported in Canada. Its age falls within Dice's (1933) reported maximum lifespan of between six and eight years for healthy captive *Peromyscus maniculatus*.

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Kumlien's Gull, *Larus glaucoides kumlieni*, on Coats Island, Northwest Territories

A. J. GASTON[1] and R. D. ELLIOT[2]

[1]Canadian Wildlife Service, Ottawa K1A 0H3
[2]Canadian Wildlife Service, P.O. Box 9158, St. John's, Newfoundland A1A 2X9

Gaston, A. J. and R. D. Elliot. 1990. Kumlien's Gull, *Larus glaucoides kumlieni*, on Coats Island, Northwest Territories. Canadian Field-Naturalist 104(3): 477–479.

Visits to Coats Island, northern Hudsons Bay, in 1983, 1985, and 1988, have documented the presence of a single breeding colony of Kumlien's Gull (*Larus glaucoides kumlieni*). Smaller numbers of Glaucous Gulls (*L. hyperboreus*) breed at this site and also at one other on the island. Thayer's Gull (*L. glaucoides thayeri*) phenotypes, to which gulls nesting on this island were previously assigned, were very rarely seen. These observations extend the known breeding range of Kumlien's Gull westward by 300 km. Relative timing of breeding in Kumlien's and Glaucous gulls appears to be similar on Coats Island in contrast to reports from other areas where they occur in sympatry.

Key Words: Kumlien's Gull, *Larus glaucoides,* distribution, Northwest Territories.

Kumlien's Gull (*Larus glaucoides kumlieni*) breeds on southern Baffin Island and on the northwest tip of the Ungava Peninsula, Quebec (Macpherson 1961; Smith 1966; Godfrey 1966). At the eastern end of Southampton Island, in northern Hudson Bay, the *kumlieni* phenotype interbreeds with Thayer's Gull (Gaston and Decker 1985), previously considered to be a separate species (*L. thayeri*, A.O.U. 1973). More recently, Godfrey (1986) considered Thayer's Gull to be conspecific with *L. glaucoides*. He specified the range of *thayeri* to include northern Southampton Island and that of *kumlieni* to extend as far as Digges Island, at the western end of Hudson Strait.

The main field distinction between adult Kumlien's and Thayer's Gulls is the colour of the primary tips. In Kumlien's Gull these are pale, almost white, usually with only small amounts of grey on the inner webs. In Thayer's Gulls they are typically blackish brown (they look black at a distance), with white windows, thus appearing similar to those of Herring Gulls (*L. argentatus*) (Smith 1966). Some intermediate phenotypes occur on eastern Southampton Island (Gaston and Decker 1985) and elsewhere (Godfrey 1986). Both taxa are distinguished from Herring and Glaucous gulls by their dark reddish eye-rings. Adult Kumlien's Gulls can be hard to tell from the larger Glaucous Gulls (*L. hyperboreus*) at a distance, but the older chicks can be easily distinguished, once they have lost their downy plumage. At this age Kumlien's Gull chicks have uniformly dark beaks, whereas Glaucous Gull chicks have flesh-colored beaks with dark tips (Cramp 1984).

The range of *Larus glaucoides* is known to extend to Coats Island, in northern Hudson Bay, on the basis of a single colony mapped by Smith (1966: Figure 13), who visited it on 3 September 1960. He recorded the birds at the colony as Thayer's Gulls, but gave no further details. Several observers have visited the colony on Coats Island during the past few years and have found practically all the gulls breeding there to be of the Kumlien's Gull phenotype. In this note we summarize recent observations and describe the colony, which is the westernmost known for Kumlien's Gull.

On 28 June 1983 AJG and R. Decker flew past the colony and noted that the gulls present did not have the black wing-tips characteristic of Thayer's Gulls. R. Decker returned to the colony by helicopter in July and confirmed that most of the gulls present were Kumlien's Gulls, and were mixed with smaller numbers of Glaucous Gulls. On 28 July 1985 the colony was visited on the ground by RDE, D. G. Noble, and J. S. Wendt. They counted 77 Kumlien's Gulls, with 12 active nests, and 33 Glaucous Gulls, with 7 active nests. All of the Kumlien's Gulls had pale wing tips. A probable Thayer's Gull, identified by its blackish wing-tips and dark irides, was present near the colony, but showed no sign of breeding.

In 1988 the colony was visited twice; by C. Rohner and K. Allard on 22 July and by AJG and K. Allard on 14 August. On the first visit, 134 gulls were counted, of which one was of the Thayer's phenotype and the remainder had pale tips to the primaries. Glaucous and Kumlien's Gulls were not distinguished. On 14 August, 138 gulls were counted, including at least 5 Glaucous Gulls. None had dark wing-tips. We counted 58 chicks in 36 broods, of which 5 were Glaucous Gulls and the rest Kumlien's Gulls. The majority of the adult gulls present were Kumlien's, but not all could be certainly identified.

The colony is on a steep, south-facing cliff, about 60 m high, situated approximately 0.7 km inland from the coast (Figure 1). Typically, Kumlien's

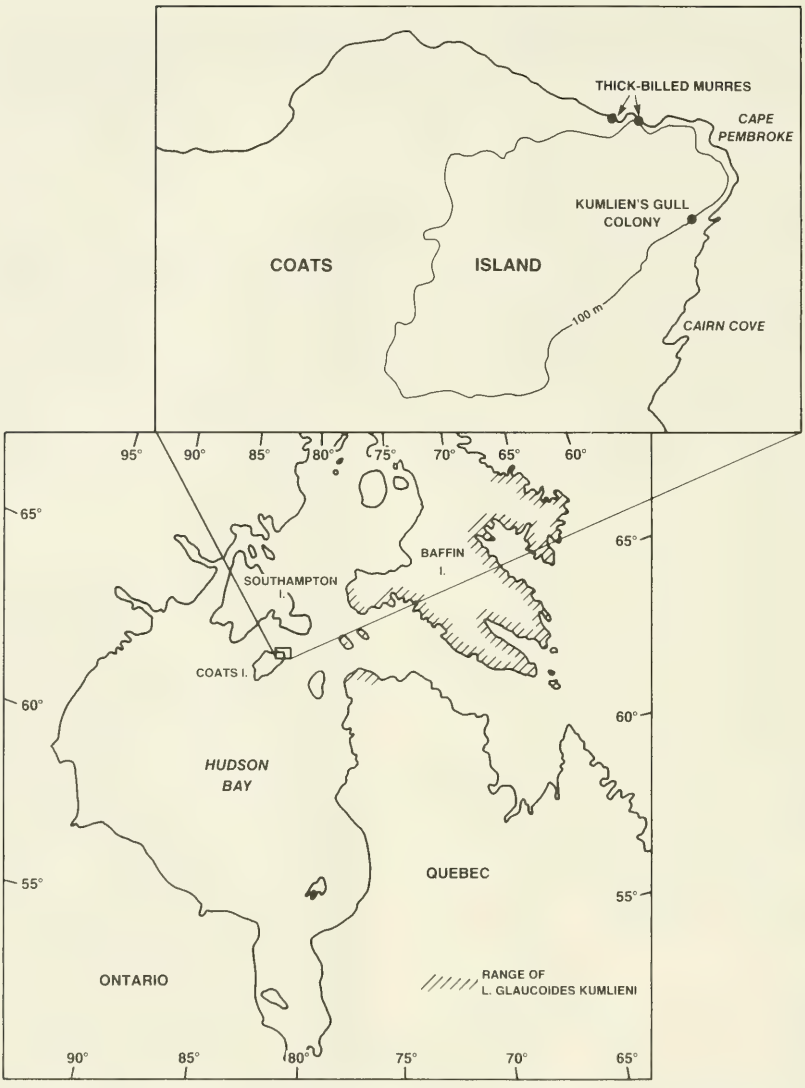

FIGURE 1. Map showing the position of the Kumlien's Gull colony on Coats Island.

Gulls nest on cliff ledges, where they are presumably secure from predation by Arctic Foxes (*Alopex lagopus*). The only other precipitous cliffs on Coats Island are on the north coast and are occupied by a colony of Thick-billed Murres (*Uria lomvia*) (Gaston et al. 1986). About 15 pairs of Glaucous Gulls nest among the murres at that location, but no Kumlien's Gulls breed there, although they are seen regularly patrolling the murre breeding cliffs, presumably in search of discarded food items or unattended eggs. It is likely that the colony described here is the only Kumlien's Gull colony on Coats Island. It extends the previously known breeding range of the race westward by 300 km.

Previous observations of breeding in Kumlien's Gulls have shown that they generally lay about two weeks later than sympatric Glaucous Gulls (Smith 1966; Gaston et al. 1985), which Smith considered a possible species isolating mechanism. To estimate relative timing of breeding, we noted the size and appearance of Kumlien's and Glaucous gull chicks on the 1985 and 1988 visits and compared them to Glaucous Gull chicks breeding at the nearby Thick-billed Murre colony. In both years the state of plumage development of the two species was similar, with Kumlien's gulls thought to be, at most, a few days behind the Glaucous Gulls. The Glaucous Gull chicks at the nearby murre colony, which

hatched in early June, were also similar in size. Hence, it appears that on Coats Island the date of laying of Kumlien's and Glaucous gulls is more similar than in other parts of their range. If the timing of breeding in 1960, when Smith (1966) visited the colony, was similar to that seen in 1988, it is likely that most breeders would have departed before his arrival on 3 September. He may therefore have considered the colony to be occupied by Thayer's Gulls on the basis of a few stragglers. It seems unnecessary to assume that the race occupying the colony has altered since 1960.

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Editor's Note: With regard to interpreting Smith's (1966) observations see also:

Snell, Richard T. 1989. Status of *Larus* gulls at Home Bay, Baffin Island. Colonial Waterbirds 12(1): 12–23.

Observations on Scent Marking in Hoary Marmots, *Marmota caligata*

JAMES F. TAULMAN

U.S.D.A. Forest Service, Wildlife Habitat and Silviculture Lab, P.O. Box 7600 SFA Station, Nacogdoches, Texas 75962

Taulman, James F. 1990. Observations on scent marking in Hoary Marmots, *Marmota caligata*. Canadian Field-Naturalist 104(3): 479–482.

Scent marking in Hoary Marmots (*Marmota caligata*) appears to serve several functions including: (1) outlining the territorial boundary, (2) imparting a "home" scent to refuge burrows in the field, (3) expressing dominance over another marmot, and (4) communicating the identity of individual marmots.

Key Words: Hoary Marmot, *Marmota caligata*, scent marking, Washington.

Armitage (1976) has provided a review of the literature on scent marking in the genus *Marmota*. Recently, Ouellet and Ferron (1988) hypothesized that scent marking in Woodchucks (*Marmota monax*) functions as an advertisement to conspecifics that a burrow is occupied. There are no published reports on scent marking in Hoary Marmots (*Marmota caligata*). Detailed descriptions of scent marking behaviors are required to analyze and interpret properly their various functions within a species (Thiessen and Rice 1976). In this paper I describe scent marking by cheek rubbing in Hoary Marmots with the intent of providing "information on the stimulus situations which elicit marking and the reactions of other animals to the marks", which is needed to

understand better this aspect of behavior (Ralls 1971).

Methods and Study Area

I observed scent marking behavior in a colony of four adults and three yearlings at a site on the south slope of Mt. Cashmere, Washington, at 2200 m elevation (47°32′N, 120°50′W). The colony territory covered about 12 ha and the four sleeping burrows were approximately 15 m apart in the central section of the territory. Data were obtained during 322 hours of observation from 18 June through 20 September 1975.

Results

Marmots mark a rock by rubbing the cheek across it using an upward motion of the head. A mark is placed on the dirt or grass by dropping down onto one shoulder and pushing the cheek across the substrate. Four different contexts of marking are described below:

(1). *Incidental marking.* Adult marmots of both sexes visited any one of the 68 refuge burrows located throughout the territory that they happened to pass while foraging. They nosed around the opening, marking a nearby boulder or dirt mound before continuing on. They ran to the nearest burrow when alarmed and also sunned on mounds or boulders by those burrows.

(2). *Marking by an adult male.* The adult male had a daily routine, lasting from mid-June through mid-August, in which he left his burrow in the morning and proceeded to traverse the periphery of the territory investigating outlying burrows and rock promontories and marking them. The risk involved in this daily ritual became evident one day when a coyote surprised the male in a boulder field and nearly caught the marmot before it dove down out of reach between two boulders. This was the only close encounter I observed between a marmot and a predator.

(3). *Marking by a parous female.* Breeding female "A" regularly passed and looked into the burrow of parous female "B" on her way out into the field each morning. She was always met with growls and barking growls (Taulman 1977) from Female B within the burrow. She responded by placing a mark on a boulder near the opening or on the dirt or grass nearby. Once she scraped up fresh dirt on the mound and rubbed her cheek across it. Her visits to the burrow ceased in mid-July when both females' young-of-the-year emerged.

(4). *Unusual instance of marking.* Of 30 intragroup chases occurring before 2 July, Female B initiated 18 (60%). She watched from her burrow as other adult females or yearlings approached the cluster of sleeping burrows in the evening, and she often gave chase when they approached within 15-25 m of her burrow. Non-parous female "C" slept in a burrow with the yearlings 15 m away from Female B's burrow, and Female C was the recipient in seven of the 18 chases, five of which occurred between 1830 and 1935 h on 20 June. Female B was very aggressive on this date, as exemplified by her pursuing Female C 100-200 m away from the sleeping burrows in each chase. On 1 July Female C began sleeping in a burrow at the periphery of the colony territory, about 350 m from her previous burrow. She foraged alone in that area during the day, and even chased Female A away from that vicinity twice on 18 July.

Female C approached the cluster of sleeping burrows on the afternoon of 21 July when no adults or yearlings were present. She proceeded to each of the burrows, cheek marking at each for 2-3 min. She visited the burrow of Female B last, and after marking it she ran quickly back down to the area where she had spent the last three weeks. Females A and B returned to their burrows about an hour later and sniffed repeatedly at the places marked by Female C and scanned the area. I did not see them mark over any of the marks left by Female C.

On the afternoon of 22 July, Female C approached the sleeping burrows when the adults and yearlings were present. She first went to her former burrow and entered; all three yearlings were in the burrow at the time. After emerging she greeted one of the yearlings and they all lay on a boulder above. As Female A approached, Female C met her and initiated several greetings in succession, after which they all lay together on the boulder. Later, as the marmots moved to a nearby area to feed, Female C initated repeated greetings with each before settling down to forage. Female B then approached Females A and C, and Female C chased Female B back to her burrow. About 15 min later Female B again approached an area where Female C was feeding. Female C again chased Female B back to her burrow where they engaged in an upright scuffle with locked incisors. They broke apart and Female C pursued Female B, nipping her rump when she caught up with her. Thereafter, Female B initiated no further chases, there were no more observed chases between adults, and Female C again slept in her old burrow with the yearlings.

Discussion

The incidental marking of burrows by foraging marmots probably serves the vital function of maintaining familiarity with the burrow (Eibl-Eibesfeldt 1975, p. 346; Johnson 1973) and is similar behavior to the "unobtrusive" marking by

male Yellow-bellied Marmots (*Marmota flaviventris*) (Armitage 1976). Because marmots must forage far afield of their "home" burrows, where accumulations of feces and used nesting materials provide a familiar smell, scent marking may serve as a device to impart the presence of a "home" smell (Ewer 1968, p. 116), or possibly a "colony" scent (Steiner 1975) or "group odor" (Steiner 1974), to an outlying burrow that will have to be occupied in the event of a predator attack. The importance of a familiar-smelling refuge burrow cannot be overstated (Ewer 1968, p. 116).

Perimeter marking by the dominant male involved a greater risk of predation and a considerably greater expenditure of energy than normal foraging. His investigation of outlying burrows and rocks was not incidental to foraging, since (a) his travels took him far from the lush patches of vegetation used by the other marmots, and (b) rather than remaining in areas offering good visibility, attractive vegetation, and nearby refuge, as would be expected (Holmes 1984), his activities took him to the more barren reaches of the territory, including a boulder field where travel was difficult, visibility was poor, and where vegetation was absent. Therefore, his territorial marking behavior must be adaptive, contributing sufficiently toward maximizing his inclusive fitness (Barash 1975) to warrant the increased risk. Possible explanations for the male's risky foray around his territorial perimeter are protection of his females and offspring and ensuring that the food resources within his territory will not be overexploited (Barash 1975). Dominant male Arctic and Columbian ground squirrels also engage in a daily patrol of their territories on which peripheral burrows and prominent landmarks are scent-marked (Steiner 1974).

Non-resident marmots observed venturing into the colony territory were not repelled by the markings, but were made aware of the presence of the local adult male and, thus, intimidated (Eibl-Eibesbeldt 1975, p. 344; Johnson 1973; Steiner 1974; Thiessen and Rice 1976). At the same time, resident marmots may have been emboldened by the presence of familiar smell out to the edges of their territory, increasing the likelihood that they would prevail in a confrontation with an intruder (Ewer 1968, p. 104–105). Non-resident marmots occasionally entered the upper area of the colony territory, coming down 100 m or more from the boundary. Before September, an intruder was always chased as soon as it was sighted by an adult, and it retreated back toward the boundary in each case.

The behavior of Female A in marking the burrow opening of Female B in response to threatening vocalizations from inside appeared to be an expression of dominance (Ewer 1968, p. 116), showing similarities in context to the descriptions of scent marking as a show of dominance in the Yellow-bellied Marmot (Armitage 1976).

Circumstances leading up to and following Female C's marking of the sleeping burrows indicate that her motivation may have been a combination of conflicting aggressive and defensive drives (Ewer 1968, p. 116). She may also have been communicating her identity to the other marmots by leaving her own scent at their burrows (Johnson 1973; Ralls 1971). Her marking of the sleeping burrows was clearly not simply a show of dominance, as that would have only applied to Female B's burrow. Also, she exhibited submissive postures in greeting the other marmots when she returned the next day, initiating repeated greetings with all, even the yearlings. Nor does it seem plausible that her motivation was territorial or incidental in nature. The communication of individual identity seems to fit this instance of marking best. This conclusion is supported by Female C's return the following day to challenge Female B and to reinstate herself into the group.

The finding that scent marking in mammals is not stereotyped, but variable and goal directed (Steiner 1974; Thiessen and Rice 1976) seems to apply well to Hoary Marmots. In addition to defining colony territory boundaries, imparting a reassuring "home" smell to refuge burrows, and to providing for an expression of dominance over another marmot, scent marking may also communicate individual identity to other group members in the same way that marmots are thought to accomplish individual recognition through exchange of mouth gland secretions during the greeting kiss (Barash 1973, 1974).

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Non-Family Wolf, *Canis lupus*, Packs

L. DAVID MECH[1] and MICHAEL E. NELSON[2]

United States Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland 20708
[1]Mailing address: North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108
[2]Mailing address: 305 W. Harvey Street, Ely, Minnesota 55731

Mech, L. David, and Michael E. Nelson. 1990. Non-family Wolf, *Canis lupus*, packs. Canadian Field-Naturalist 104(3): 482–483.

Three non-family Wolf packs of three are described from Minnesota. All included a male-female pair, and the extra member was related to one member in two cases, and probably related in the other.

Key Words: Wolf, *Canis lupus*, pack, pair bond, radio-tracking, telemetry.

Wolf (*Canis lupus*) packs are generally families of adults and offspring of various ages (Murie 1944; Mech 1970). Usually packs arise when an adult male and female meet, pair-bond and produce offspring (Rothman and Mech 1979; Fritts and Mech 1981). We refer to such packs as "family packs" and to all other packs as "non-family" packs. We have found no records of Wolf packs originating in ways other than through splitting of larger packs (Mech 1966, 1986), a phenomenon not well understood but which probably still results in family packs.

This note reports on three non-family Wolf packs studied in the central Superior National Forest of northeastern Minnesota during winter 1986-1987. Each pack included three members, all of which were radio-tagged and aerially radio-tracked and observed (Mech 1974).

The Garden Lake trio consisted of a male that recently had dispersed from one pack and in November 1986 began associating with two lone 30-month-old females which probably were sisters, based on their overlapping ranges. From 24 November 1986 through 3 April 1987, these three were found together by radio on 49 occasions and were observed together but with no other Wolves 19 times (Mech and Nelson 1989). Both females produced pups that summer.

The Little Gabbro trio included a female at least 7-years old whose mate had died in July 1986. By 15 August 1986, 2-year-old male Wolf 6689 which had dispersed from a neighboring pack began associating with this female. On 15 of 15 occasions from 15 August through 11 November 1986 the two were found together by radio. On 16 September and 15 October 1986, 1-year-old male Wolf 6875, a brother to 6689 was found by radio to be with or near the pair. The three were then found together by radio on 6 of 7 occasions from 17 November through 18 December 1986 and were observed together three times until 23 December 1986 when the female was killed in an illegal snare. The two sibling males were then found together by radio 7 of 10 times they were located between when the female died and 22 January 1987. After that, they remained apart permanently.

The Pike Lake trio was formed about 1 December 1986, when male Wolf 6041, at least 7-years old, and male 6899, his 19-month-old son, began associating with 19-month-old female 413 who had dispersed from a neighboring pack. Wolf 6041's most recent mate had died in October 1986.

Members of the new assemblage were found together by radio on 38 of 43 occasions from 1 December 1986 through 23 March 1987, and were seen together 12 times between those dates. After that, 6899 left the pair and began moving alone. From 26 March through 21 October, 6899 was found with the pair only three of 31 times.

Although none of these packs of Wolves was a natural family, all had in common a male-female pair. In two of the three cases the extra member was related to one of the others, and in the third case the extra member was probably related. All three associations remained intact for several months, but in two the extra member left after late March, and in the third case the death of one of the pair members ended the observation prematurely. One of the surviving packs produced pups the following summer (Mech and Nelson 1989), and the other a year later.

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Mobbing of a Long-tailed Weasel, *Mustela frenata*, by Columbian Ground Squirrels, *Spermophilus columbianus*

ALTON S. HARESTAD

Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia V5A 1S6.

Harestad, Alton S. 1990. Mobbing of a Long-tailed Weasel, *Mustela frenata*, by Columbian Ground Squirrels, *Spermophilus columbianus*. Canadian Field-Naturalist 104(3): 483–484.

A Long-tailed Weasel attacked a Columbian Ground Squirrel and was subsequently mobbed by two other ground squirrels. The weasel terminated its attack and fled.

Key Words: Long-tailed Weasel, *Mustela frenata,* Columbian Ground Squirrel, *Spermophilus columbianus*, British Columbia, mobbing.

On 24 May 1987 in a subalpine meadow (1829 m) near Blackwall Peak (49°5′N, 120°46′W) in Manning Provincial Park, British Columbia, I observed a Long-tailed Weasel (*Mustela frenata*) attack a yearling Columbian Ground Squirrel (*Spermophilus columbianus*). The ground squirrel was sitting next to a 20 cm-in-diameter log and its view of the area on the other side of the log was obscured. On the other side of the log, a Long-tailed Weasel traveled from a small Engelmann Spruce (*Picea engelmannii*), past a stump, and towards the log. The weasel did not appear to be stalking the ground squirrel but was moving about investigating various places along its route. When the weasel climbed to cross the log, it was about 30 cm from the ground squirrel. The two animals stood still, looked at each other for a few seconds and then the weasel rushed toward the ground squirrel. The ground squirrel scurried away and uttered two alarm calls while it was chased by the weasel. Within about 2 m, the weasel caught up to the ground squirrel and grabbed it with its mouth. The ground squirrel and weasel tumbled about while the ground squirrel gave a series of loud

sustained squeals. The ground squirrel broke free only to be caught again and continue its squealing. During this attack, two other ground squirrels emerged from a nearby burrow, joined the fracas, and attacked the weasel. One of the joining ground squirrels was a yearling but I was unable to classify the other one. After a few seconds, the weasel broke off its attack and ran down slope with one of the ground squirrels pursuing it for a distance of 1.5 to 2 m. While I watched the chase, the other two ground squirrels entered burrows. I did not see if or how badly the first ground squirrel was injured. The ground squirrel that chased the weasel returned to the site and entered a burrow.

I do not know if the ground squirrels were siblings or otherwise related. Because of the short distance between where the first ground squirrel encountered the weasel and the burrow from which the other ground squirrels emerged to join the fight, they could have been from the same family group. Mobbing is an antipredator behaviour that has been observed for many species of birds (Curio 1978). Fewer reports occur for mammals (Smythe 1970; Owings and Coss 1977; Morse 1980). One explanation for mobbing, "aiding a distressed relative", is based on kin selection (Curio 1978). Another explanation of mobbing is that it is a means of cultural transmission by which a young individual learns to recognize a predator (Curio 1978). Because I do not know if the ground squirrels that I observed were related, their mobbing of the weasel could be explained by either of these hypotheses.

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Possible Use of Wolf, *Canis lupus,* Den Over Several Centuries

L. DAVID MECH and JANE M. PACKARD[1]

North Central Forest Experiment Station, 1992 Folwell Ave., St. Paul, Minnesota 55108
[1]Department of Wildlife and Fisheries Sciences, Nagle Hall, Texas A&M University, College Station, Texas 77843-2258

Mech, L. David, and Jane M. Packard. 1990. Possible use of Wolf, *Canis lupus*, den over several centuries. Canadian Field-Naturalist 104(3): 484–485.

Radiocarbon dating of bones found at a Wolf den on Ellesmere Island suggest it probably was used by Wolves over 700 years ago.

Key Words: Wolf, *Canis lupus*, den, Ellesmere Island, Musk-ox, *Ovibos moschatus.*

Wolves (*Canis lupus*) sometimes use dens in which to rear pups for several consecutive years, or intermittently over long periods. The longest documented case involves the East Fork den in Denali National Park (formerly Mount McKinley National Park), Alaska. Murie (1944) first recorded Wolves using that den in 1940 and 1941, and United States National Park Service records indicate that it has been used intermittently since. It has also been used annually from 1986 through 1989 (LDM, unpublished data). The present report provides evidence for the possible use of a den on Ellesmere Island, Northwest Territories, over a period of 700 years or more.

The den was a rock cave at the base of an igneous-intruded sandstone rock face (Mech 1987, 1988) on west-central Ellesmere Island (80°N, 86°W). The entrance was about 1-meter wide, and tunnels and a chamber stretched for several meters. Outside the den were nearby boulders and rock outcrops throughout which smaller tunnels used by pups wound. The den overlooked a small valley through which a stream flowed some 30 meters below. Seven adults and six pups used the den in 1986, six adults and five pups in 1987, and four adults and four pups in 1988.

Numerous old and fresh bones of prey, primarily Muskox (*Ovibos moschatus*), littered the area

within about 10 meters of the den, some of which were partly covered with soil. Adult Wolves were observed carrying pieces of prey including bones back to the den. Both adults and pups chewed fresh bones around the den.

Three well-weathered Muskox bones were collected and radiocarbon dated by GeoChron Laboratories, Cambridge, Maine[1]. One was considered post-1950 because of incorporation of carbon from nuclear testing, one was aged at 232 ± 70 years, and one 783 ± 200 years. The last would indicate Wolf activity around the den sometime between the years 1005 and 1405.

These bones do not prove Wolf use of the den centuries ago, since conceivably Wolves or other animals brought the old bones to the den more recently. However, hundreds of hours of watching Wolves around the den failed to demonstrate that Wolves brought back any bones other than those with at least some flesh attached. Furthermore, if Wolves tended to bring old bones to the den, there should have been hundreds of bones there, since such bones are common on the surrounding tundra. An alternate explanation for the presence of the old bones around the den is that Muskoxen just died there long ago.

Considerable ground travel within 30 km of the den indicated no other rock caves large enough to fit adult Wolves. This fact, plus the permafrost that prevented digging of dens, probably helps explain why this den, which was so well suited to sheltering adult Wolves and pups, has been used for so many years.

[1]Mention of commercial manufacturers does not imply endorsement by the United States federal government.

Acknowledgments

Funding for this project was provided by the National Geographic Society. Logistical support came from Atmospheric Environment Service and the Polar Continental Shelf Project. We also thank Renewable Resources, Northwest Territories for the permit to study this den.

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Received 6 June 1989
Accepted 6 March 1990

News and Comment

Canadian Society of Zoologists, Survey of Zoological Collections

The CSZ Canadian Zoological Collections Advisory Committee is conducting a survey of collections of zoological specimens other than terrestrial arthropods. All sizes of collections will be included but the emphasis is on locating and surveying small or potentially orphaned collections. Because the intent is to ensure the preservation of collections of systematic importance, the Society will request information only about specimens with collection data (at least locality and date).

The Canadian Heritage Information Network will support the project by entering the data into a database on their mainframe computer. The results of this survey will be compiled, summarized and published as hard copy or electronically. Addresses or information on contents of individual collections will be made public only with permission.

The present announcement is to solicit names and addresses of people to whom the questionnaire should be sent. We are particularly interested in locating small private collections that may not have been reached by previous surveys such as those of the Canadian Museum Association. Do you know of collections held by scientists retired from university or government laboratories, or presently working in other institutions or private companies? By invoking the collective memory of Canadian zoologists and naturalists, it may be possible to reach many of these people. Please forward information to:

DR. MARY NEEDLER ARAI

Chair, CSZ Canadian Zoological Collections Advisory Committee, Department of Biological Sciences, University of Calgary, Calgary, Alberta T2N 1N4. Telephone: (403) 220-5281; Fax: (403) 289-9311.

Étude des collections de zoologie de la Société canadienne de zoologie

Le comité consultatif de la SCZ pour les Collections canadiennes de zoologie est présentement en train de faire une étude sur les collections de spécimens zoologiques, excluant les arthropodes terrestres. Les collections de toute grandeur seront inclus mais l'emphase est sur la location et un relèvement de toutes les collections petites et possiblement orphelines. La Société demandera des informations seulement à propos des spécimens avec une collection de données (au moins le lieu et la date). Ceci sera fait ainsi parce que l'intention est d'assurer la conservation des collections d'importance systématique.

Le Réseau canadien d'information sur le patrimoine supportera le projet en entrant les données dans une base de données dans leur ordinateur principal. Les résultats de cette étude seront compilés, résumés et publiés en tant que document ou par poste électronique. Les adresses et les informations sur le contenu de chaque collection sera publique seulement sous permission.

Cette présente annonce est pour solliciter les noms et les adresses des gens à qui on peut envoyer un questionnaire. Nous sommes particulièrement intéressés à retrouver les petites collections privées qui n'auraient pas été retrouvées dans les études antécédentes telle que celle faite par l'Association Canadienne des Musées. Seriez-vous au courant d'une ou plusieurs collections de scientistes qui sont à leur retraite et qui auraient travaillé dans des laboratoires universitaires ou gouvernementaux, ou qui sont présentement en train de travailler dans d'autres institutions ou pour des compagnies privées? En invoquant la mémoire collective des zoologistes et naturalistes canadiens, il sera peut-être possible de rejoindre tous ces gens. S.V.P. envoyez l'information à:

DR. MARY NEEDLER ARAI

Directrice, Comité Consultatif de la SCZ pour les Collections Canadiennes de Zoologie, Département des Sciences Biologiques, Université de Calgary, Calgary, Alberta T2N 1N4. Téléphone: (403) 220-5281; Fax: (403) 289-9311.

Request for Assistance: Alberta Bird Atlas Project

In 1991, the Alberta Bird Atlas Project will be in its final year of collecting data on breeding birds. We are inviting birders to come visit Alberta and participate in our big push to fill in all the gaps. Assistance would be appreciated anywhere in the province, but we particularly need volunteers to take part in remote area trips to Alberta's north country and mountainous areas. Familiarity with boreal bird species as well as wilderness survival skills are essential. In many of the remaining blocks, canoeing experience would be desirable.

Access to some of the sites can be gained by road and canoe, while others can only be reached by air. Travel assistance, lodging, and support can be provided within Alberta. Financial assistance with other travel and with living expenses may be available.

In northern Alberta, June and July are the key months for atlas work. Volunteers for such northern work should be able to commit at least one week to road-accessible blocks and 10 days for fly-in blocks. If you have shorter periods of visits available, there will be many squares in southern Alberta on which assistance would be helpful. Atlassers who worked on blocks in northern Ontario are particularly encouraged to come to Alberta and reacquaint themselves with the boreal forest bird fauna.

For more information, please contact Alberta Brule, Executive Director, Alberta Bird Atlas Project, c/o Provincial Museum of Alberta, 12845-102 Avenue, Edmonton, Alberta, Canada, T5M 0L9; telephone 403-453-9163.

SEANNE MACKENZIE

Book-review Editor's Annual Report, Volume 103

Each year, after receiving the final issue of the latest volume of *The Canadian Field-Naturalist*, I am amazed at the number of books that pass through my shelves and the number of friends that I make with this job. Both I count as benefits and the reason that I keep doing this, even though I moved from the Ottawa region over 17 years ago.

Speaking of friends, I make a plea every year for both new reviewers and for experienced reviewers to keep contacting me when interesting titles are published. I wrote over 300 letters to request reviews or publications last year and just do not have the time to keep up with every one of my more than 220 active reviewers. We received 183 complimentary books last year and many of them are still on my shelves. In the same period 196 reviews were complete and edited and 139 of them published. The number of new titles listed, 439, was down from the 596 of the previous volume, but about standard for recent volumes. All of these statistics represent significant increases when compared to the earlier years for which I have kept records.

Reviews published in our journal should be between 1 and 2 pages, double-spaced in length. The opinions expressed in the review are those of the reviewer. Editing is mostly for grammar, style, and length. It is also assumed that those offering to write reviews have the appropriate expertise. The editors do have the final decision as to whether a review is published. Edited versions are provided to the author prior to publication as galley proofs. Review guidelines are available to anyone requesting them. The reviewer gets to keep the complimentary copy of the book. Anyone interested should contact the Book-review Editor at the address below, indicating the areas that you are interested in reviewing and/or titles from our lists.

WILSON EEDY

R.R. #1, Moffat, Ontario L0P 1J0

Minutes of the 111th Annual Business Meeting of The Ottawa Field-Naturalists' Club: 9 January 1990

Place and Time: Auditorium, Victoria Memorial Museum Building, Metcalfe and McLeod Streets, Ottawa, 20:12 hrs
Chairperson: Jeff Harrison, President
Attendance: Thirty-eight people attended the meeting

1. Minutes of the Previous Meeting

Doreen Duchesne, Recording Secretary, read the minutes of the 110th Annual Business Meeting. It was moved by Jeff Harrison (2nd Barbara Campbell) that the minutes be approved.

(Motion Carried)

2. Business Arising from the Minutes

a) The Club has not yet found permanent office space for its activities. It was hoped that the Club would be allocated space by the National Museum of Natural Sciences when the Museum of Civilization moved out. But, because the NMNS is reorganizing, it isn't clear at this time whether the OFNC will get space. Someone from outside the Club is currently attempting to house environmentally-related interest groups in one location. The OFNC could be one of those groups.

b) A new membership brochure was produced last year. The new version is an improvement over the old one.

3. Financial Report

a) The financial statements were presented by Janet Gehr, the outgoing Treasurer. She noted an increase in Members' Equity from $90 870 in 1988 to $114 776 in 1989. Fixed assets were up considerably because of the purchase of a desktop publishing system. This was paid for by a bequest received in 1989, resulting in a large increase in "Donations and grants" in the Statement of Members' Equity.

Other highlights noted include: an increase in funds for the Alfred Bog (see Note 4 to the Financial Statements); an increase in cash (primarily from investments); an increase in depreciation (see Note 3) because of the desktop computer; an increase in "Special publications" because of the publication of *Lichens of the Ottawa District*; increased interest earned for both the OFNC and the CFN; and a decrease in CFN revenue from reprints (1988 having been an unusually profitable year for reprints).

b) One member wanted to know what the loss of $650 under "Other sales" in the OFNC's Statement of Operation was about. This figure results from the fact that the Club has purchased a number of copies of Dan Brunton's book (*Nature and Natural Areas in Canada's Capital*) for resale. Normally this item would be shown as inventory, but in the Club's financial statements, revenue from sales is shown net of the cost of the items sold, these costs being entered into the books when incurred.

It was moved by Janet Gehr (2nd Frank Pope) that the Financial Report be accepted.

(Motion Carried)

4. Nomination of Auditor

a) Monty Brigham audited the The Ottawa Field-Naturalists' Club books for the 1988/89 fiscal year and found everything in order. Frank Pope informed Club members that Brigham was stepping down as auditor. He described Brigham as a multi-faceted personality who was known to various people as a professional accountant, translator for the deaf, radio and television personality, OFNC lecturer and excursion leader, bird count enthusiast and producer of nature tapes and records. He emphasized Brigham's valuable contribution to the Club's accounting system, which is fairly complex since considerable sums of money are involved. As far back as the 1960s, Brigham recognized the need for a more professional approach to keeping the Club's books. Over the years, he actively worked to improve the system in a number of capacities including being the Club's Treasurer for 3 years and auditor for 13 years.

Frank Pope was pleased to move a vote of thanks to Monty Brigham for his significant contribution to The Ottawa Field-Naturalists' Club (2nd Bill Gummer).

(Motion Carried)

b) Frank Pope moved the appointment of Janet Gehr as auditor of the accounts of The Ottawa Field-Naturalists' Club for the 1989/90 fiscal year (2nd Don Davidson).

(Motion Carried)

5. Report of Council

The reports were read and discussed as follows:

a) Awards Committee

The report was read by Jeff Harrison. There were no questions or comments.

b) Birds Committee

The report was read by Roy John. There were no questions or comments on this report. However, one member wanted Frank Pope's recognition of Monty Brigham's contributions to the Club to be published in *The Canadian Field–Naturalist*. Bill Gummer said that it would be published in the *CFN* as part of these minutes and that it should also be published in *Trail & Landscape*. Another member, who asked if there was a record of people who have worked on various Committees, was told that Committee membership lists are published annually in *Trail & Landscape*.

c) Computer Management Committee

The report was read by Ken Strang. There were no questions or comments.

d) Conservation Committee

The report was read by Jeff Harrison. Pope apologised to members for the delay in mailing honorary deeds to those who made donations to the Alfred Bog. The Nature Conservancy is responsible for the delay. The certificates have been printed but a calligrapher is needed to enter people's names.

Someone wanted to know what the *Green Line* is. Michael Murphy explained that it's a one-page newsletter dealing with local environmental concerns which will be published regularly in *Trail & Landscape* beginning with the next issue. Some provincial concerns may be covered as well.

e) Education and Publicity Committee

The report was read by Roy John. A comment was made that it was nice to see the Committee being active.

f) Excursions and Lectures Committee

The report was read by Roy John. There were no questions or comments.

g) Executive Committee

The report was read by Ken Strang. Jeff Harrison said this was a new report. He also mentioned that a special meeting will be held February 10th to exchange views and to give future direction to the Club. About 20 people will be invited, including long-term members, short-term members and others who are extensively involved in Club activities. One person, who wanted to know where it will be held, was told Scott House in Hull. Someone wanted to know if the outcome of the meeting would be published anywhere. Harrison said that the meeting will be broken up into small groups, each with a secretary. One person will collate all of the minutes afterwards. He thought there would be too much information for the minutes to be published in their entirety but a summary could be printed in *Trail & Landscape*.

h) Finance Committee

The report was read by Jeff Harrison. There were no questions or comments.

i) Macoun Club Committee

The report was read by Roy John. There were no questions or comments.

j) Membership Committee

The report was read by Ken Strang. Someone, who said it was good to see an increase in membership, wondered if it was because of the new brochure or the activities of the Education and Publicity Committee. There are probably a number of reasons for this increase, including the sale of Dan Brunton's book and a new awareness of environmental issues.

k) Publications Committee

The report was read by Jeff Harrison. A member asked how many copies of Brunton's book had been sold and what were the financial implications. Gummer said he last heard that about 3300 copies had been sold, which wasn't enough to cover publication costs. Two ads recently placed by the *Citizen* might have increased sales significantly, however. In response to a query on the number printed, Gummer said that 10000 had been printed and that 5000 of these had to be sold to break even.

It was moved by Jeff Harrison (2nd Sheila Thompson) to accept the Report of Council.

(Motion Carried)

6. Report of Nomination Committee

a) Bill Gummer reported the following members nominated for the 1990 Council:

President: Jeff Harrison (*Executive*), Vice-Presidents: Roy John (*Excursions and Lectures*), Don Cuddy (*Conservation*), Treasurer: Mick Scromeda*, Recording Secretary: Elizabeth Fox, Corresponding Secretary: Eileen Evans.

Other Council members:

Ronald Bedford (*Publications*), Barry Bendell (Macoun Field Club); Steve Blight*, Colin Gaskell*, Bill Gummer (Awards), Paul Hamilton*, Elizabeth Morton, Frank Pope (*Finance*), Bill Cody, Francis Cook, Don Davidson, Enid Frankton, Deirdre Furlong (Education and Publicity), Ken Strang, Doreen Watler* (Membership).

Notes:
1. Asterisks (*) indicate new members of Council
2. Committee Chairpersons are those with a Committee name shown in parentheses. Other Committee Chairpersons are: Suzanne Blain (Computer Management) and Gordon Pringle (Birds)
3. Standing Committees are shown italicized

b) The following Council members resigned during the year (+) or are resigning now:

Martha Aksim (*Corresponding Secretary*)
Ellaine Dickson
Doreen Duchesne (*Recording Secretary*)
Janet Gehr
Catherine O'Keefe
Karen Richter
John Sankey +
Austin Taverner

Gummer noted that Ellaine Dickson had been a Council member for many years.

It was moved by Gummer (2nd Dickson) that the slate of officers nominated for the 1990 Council be approved.

(Motion Carried)

Jeff Harrison thanked new Council members for donating their time on Council. He also thanked retiring and other Council members who served in 1989 for their contributions at meetings and behind the scenes. He singled out Doreen Duchesne for her superb job as Recording Secretary and Ellaine Dickson for her longstanding contribution to the Club.

7. New Business

a) Ellaine Dickson thanked Christine Henri for having provided the refreshments for a number of years.

b) On behalf of the Club's birders, Roy John thanked Larry Neely for putting a lot of effort into keeping the bird status line up-to-date and for providing information useful to both casual and serious birders.

c) Michael Murphy thanked Lisa Meyboom for having co-ordinated the volunteer mailing of *Trail & Landscape*, which is a big job.

d) One member wanted to know how the Club dealt with the public on issues like the proposed Britannia development. Jeff Harrison said there was no official policy but that he and the Chairperson of Conservation Committee often speak on behalf of the Club. He also mentioned that Dan Brunton had been speaking to the media, but as a consultant not a Club official. Michael Murphy said that if the media calls him wanting to know what the Club's position is on an issue, he contacts the best person to deal with it. For example, if it's related to conservation, he calls the Chairperson of Conservation Committee or the President. Harrison said that the Club's approach has been reactive in the past. Deirdre Furlong noted that Club members want to deal with environmental issues in different ways. (Note: Many of the calls are received at the Club number and are referred to the most appropriate spokesperson.)

8. Adjournment

At 21:35, Frank Pope (2nd Barbara Campbell) moved that the meeting be adjourned. Jeff Harrison mentioned that a video featuring "The Man Who Planted Trees" would be shown, followed by refreshments in the Salon.

DOREEN DUCHESNE
Recording Secretary

The Ottawa Field-Naturalists' Club
Financial Statements for the Year Ended 30 September 1989

The Ottawa Field-Naturalists' Club
BALANCE SHEET
30 September 1989

	1989	1988
Assets		
CURRENT ASSETS		
Cash	$149,649	$133.732
Accounts receivable	14,054	21,245
Interest receivable	1,577	464
Prepaid expenses	1,395	
	166,675	155,441
FIXED (Note 3)	7,674	1,030
LAND — Alfred Bog	3,348	3,348
	$177,697	$159,819

Liabilities, Funds and Members' Equity	1989	1988
CURRENT LIABILITIES		
Accounts payable	$ 38,573	$ 46,662
Deferred income	11,700	12,000
	50,273	58,662
FUNDS (Note 4)	6,648	4,287
LIFE MEMBERSHIPS	6,000	6,000
MEMBERS' EQUITY	114,776	90,870
	$177,697	$159,819

The Ottawa Field-Naturalists' Club
Statement of Members' Equity
Year Ended 30 September 1989

	1989	1988
EXCESS INCOME (EXPENDITURES)		
Ottawa Field-Naturalists' Club	$ 366	$ 4,046
Canadian Field-Naturalist	9,092	12,212
	9,458	16,258
OTHER INCOME (CHARGES)		
Donations and grants	13,083	1,993
Trail and landscape index	—	(1,659)
Records and tapes	1,365	(2,440)
	23,906	14,152
MEMBERS' EQUITY, BEGINNING OF YEAR	90,870	76,718
MEMBERS' EQUITY, END OF YEAR	$114,776	$ 90,870

The Ottawa Field-Naturalists' Club
Statement of Operations — OFNC
Year Ended 30 September 1989

	1989	1988
INCOME	$13,889	$13,131
Trail and landscape	440	416
Subscriptions		
Back numbers	16	222
Interest	2,521	1,514
Other sales	(650)	203
	16,216	15,486
EXPENSES		
Trail and landscape		
Printing	3,821	4,031
Circulation	284	371
Production	204	758
Honorarium	660	605
Committees (Net)		
Excursions and lectures	(75)	(1,839)
Membership	1,337	1,259
Macoun Club	1,112	702
Conservation	66	120
Birds	97	121
Education and publicity	57	421
Computer	337	490
Affiliation fees	230	230
Office assistant	790	520
Office supplies and expenses	2,678	2,220
Special publications	1,304	—
Depreciation	2,948	1,431
	15,850	11,440
EXCESS OF INCOME OVER EXPENSES	$ 366	$ 4,046

The Ottawa Field-Naturalists' Club
Statement of Operations — CFN
Year Ended 30 September 1989

	1989	1988
INCOME		
Membership fees	$ 9,500	$ 9,500
Subscriptions	24,883	23,582
	34,383	33,082
Publication		
Reprints	13,029	25,023
Plates and tab settings	6,477	3,513
Extra pages	20,801	26,700
Back numbers	557	417
Interest	10,086	6,123
Exchange	2,612	1,520
	87,945	96,378
EXPENSES		
Publishing	53,920	57,975
Reprints	5,859	11,436
Circulation	7,128	5,976
Editing	1,819	2,849
Office assistant	3,656	3,360
Office supplies	4,391	596
Honorarium	2,080	1,974
	78,853	84,166
EXCESS INCOME OVER EXPENSES	$ 9,092	$12,212

The Ottawa Field-Naturalists' Club
Notes to the Financial Statements
30 September 1989

1. *Authority and Activities*

The Ottawa Field-Naturalists' Club is a non-profit organization incorporated under the laws of the Province of Ontario (1884). The Ottawa Field-Naturalists' Club promotes the appreciation, preservation and conservation of Canada's natural heritage; encourages investigation and publishes the results of research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with organizations engaged in preserving, maintaining or restoring environments of high quality for living things. Membership is open to any person or family, upon application and payment of dues. Payment of the Annual Dues as set out in the By-laws will be a necessary condition for the continuance of Membership.

2. *Significant Account Policies*

Memberships, subscriptions and donations are recorded as received. All other revenues and expenditures except for inventory are accounted for on the accrual basis. Memberships are allocated to *The Canadian Field-Naturalist* publication on a pre-determined percentage.

Supplies, records, tapes and other items held for resale are expensed when purchased.

Fixed assets are recorded at cost and are depreciated on a straight-line basis.

Life memberships paid since 1977 are recorded at the fee in effect at that time. There are 38 life members.

3. *Fixed Assets*

	1989	1988
Cost	$16,748	$7,156
Accumulated Depreciation	9,074	6,126
Net book value	$ 7,674	$1,030

4. *Funds*

	1989	1988
Baldwin Memorial Fund	$ 358	$ 358
Seedathon	964	1,104
Anne Hanes Memorial Fund	790	865
Alfred Bog	4,536	1,960
	$6,648	$4,287

Auditor's Comment

I have examined the balance sheet of The Ottawa Field-Naturalists' club as at September 30, 1989 and the statements of operations for the year ended. My examination was made in accordance with generally accepted auditing standards, and accordingly included such tests and other procedures as I considered necessary in the circumstances.

In my opinion, these financial statements present fairly the financial position of the Corporation as at September 30, 1989 and the results of its operations for the year then ended in accordance with generally accepted accounting principles applied on a basis consistent with that of the preceeding year.

F. MONTGOMERY BRIGHAM

Ottawa, Canada
5 January 1990

Committee Reports for 1989

Awards Committee

Committee recommendations, based on 16 nominations, were accepted by Council. Awards were made, as described below, at the Soirée held April 29. Citations were read and subsequently published in *Trail & Landscape*.

(1) *Honorary Member*: none, since the Club's quota was full.

(2) *Member of the Year* and *Conservation Awards*: both to Frank Pope, for his work towards the acquisition of Alfred Bog and his extensive involvement in Finance Committee activities.

(3) *Service Award*: Lois Cody, for bookkeeping and other tasks.

(4) *Anne Hanes Natural History Award*: Dan Brunton, for his book *Nature and Natural Areas in Canada's Capital*.

(5) *President's Award*: Marg Benson, for her work in the Peregrine Falcon release program.

Small brass plates, showing the year of the award, have now been obtained for each of the winners, to date, of the Anne Hanes Award.

The Committee is concerned with the small number of nominations and asks all other Committees as well as the general membership to consider useful nominations.

BILL GUMMER (Chairperson)

Birds Committee

The Ottawa-Hull Audubon Christmas Bird Count has been reorganized with responsibility now shared between the Ottawa Field-Naturalists' Club and the Club des Ornithologues de l'Outaouais. Co-compilers have been appointed from the sponsoring Clubs and a post-count meeting in 1989 will be held in Hull.

A working group has been formed to co-ordinate OFNC participation in the Ontario Rare Bird Breeding program. This is a provincially-based five-year program intended to inventory breeding sites for a short list of rare or sensitive species. It is hoped that this inventory will assist in the protection of these sites.

We continue to operate five major winter feeding stations. The Seedathon this fall raised approximately $2,000 for this purpose.

A draft of a members' code of ethics has been produced for publication in *Trail & Landscape* and inclusion in the new members package.

GORDON PRINGLE (Chairperson)

Computer Management Committee

The Committee ensures the efficient and controlled use of the computer assets of the Club. It maintains and improves existing systems and increases awareness of how the computer can help other Committees with their various needs. Here are some achievements:

We set up two software packages, FASTBACK and Calendar Creator Plus. FASTBACK improves backup procedures. Calendar Creator Plus helps schedule Committee and Club events.

The Committee decided that the existing membership system would have to be completely rewritten; the system was not maintainable and it did not adequately suit the Club's needs. Discussions with Membership Committee helped identify requirements. The new system design includes: postal code checking and bundle naming, to help the Club bundle *Trail & Landscape* and remain eligible for the lowest postage rates; volunteer handling, to help maintain volunteer lists and to encourage their use; and achievement recording, to help the Awards Committee.

The existing membership system was improved to help Membership Committee with renewal notices and membership reports.

An expanded Computer Management Committee evaluated *Trail & Landscape* word processing and desktop publishing needs. The Committee advised Council about prospective solutions and arranged the purchase of a computer, laser printer and software. The Committee helped with the installation and gave the editor of *Trail & Landscape* technical support.

SUZANNE M. BLAIN (Chairperson)

Conservation Committee

The Committee met formally on ten occasions in 1989 and dealt with a wide range of conservation matters. Some of the more prominent activities include: a review

of the draft Ontario wetlands policy; comment on the proposed Ontario Sustainable Development Act; input to the City of Ottawa Official Plan review; and comment on the proposed changes to the structure of conservation authorities in Ontario. On behalf of the Club, the Committee also joined with other groups and individuals to protect parklands and natural areas at places such as Alfred Bog, Gatineau Park, Stony Swamp, Constance Creek, Westmeath Park, Findlay Creek and Britannia Park. The Committee continues to represent Club interests on the Marlborough Forest Advisory Committee and is monitoring a number of issues including the review of Ontario's Environmental Assessment Act, the re-zoning and potential development of natural lands in and about Ottawa and the development of a waste management plan for Ottawa-Carleton. The Committee is looking forward to 1990, when we intend to be even more effective environmental spokespersons both externally and internally (to Club members) through the *Greenline* and other communications.

D. G. CUDDY (Chairperson)

Education and Publicity Committee

Seven meetings were held in 1989. The Committee effectively established the regular use of agendas and minutes, and created a Committee job list. Efforts were concentrated on increasing Club publicity, dealing with public requests and expanding the sale of Club articles.

A Club flyer was developed and distributed to nature and outdoor stores. Monthly meetings were advertised through the local media. Committee members organized volunteers for the Club display, which was transported to eight events, including the Ottawa Duck Club Nature Art Show, New Members' Night and various environmental shows. OFNC judges awarded three prizes for natural science projects at the Ottawa Science Fair. Club sales throughout the year amounted to approximately $725.

The Committee was asked on several occasions to show the display and supply speakers and educational materials; all but one request were filled.

DEIRDRE FURLONG (Chairperson)

Excusions and Lectures Committee

The Committee organised ten evening meetings with speakers who made presentations on a wide variety of subjects. The Committee also hosted another successful Soirée.

Ten full-day and eighteen half-day field trips to local areas were arranged. In addition there were five evening, two night and one overnight trips. Eight bus trips, to places outside the local area were scheduled, but one was cancelled and a second was converted to a car excursion.

The Committee also set up a four-day trip to Point Pelee to coincide with the spring migration. And, a workshop and tour at Carleton University were arranged.

The varied purposes of these trips reflects the range of interests of Club members. Bird-oriented trips led the way with 44% of the total, followed by general interest outings (28%). Botany-related trips accounted for 16% of the total and insects 5%. The remaining outings were devoted to mushrooms, fossils and amphibians (7%).

ROY JOHN (Chairperson)

Executive Committee

The Committee met three times in 1989. The following issues regarding the Club's operations were reviewed and improved:

Length of Council meetings: The discussion regarding communications sent and received has been reduced. In the coming year, attempts will be made to limit the time spent on routine Committee reports.

Providing more environmental information to our membership: An insert dealing with environmental matters will be appearing regularly in *Trail & Landscape*. The Conservation Committee will co-ordinate this activity. The Excursions and Lectures Committee was encouraged to invite speakers to give brief talks on specific environmental issues at monthly meetings.

Designation of a volunteer co-ordinator: To increase volunteer participation in Club activities, Karen Richter encouraged Committee Chairpeople to contact potential volunteers. She later contacted those who had not been approached by anyone else.

Future directions for the Club: The general public is getting increasingly interested in environmental problems. The Committee felt that the Club could provide educational guidance in this area. Planning is underway to discuss this issue, among others, at a specially-organized event early in the new year.

Fundraising Committee: An ad-hoc committee formed to address specific fundraising objectives might be beneficial to the Club. In the coming year, the Executive will discuss its operation and mandate.

JEFF HARRISON (Chairperson)

Finance Committee

The Committee met four times during the year. It addressed itself to a review of Club policies regarding donations and the financial reserve required. The report on costs associated with publishing the *Canadian Field-Naturalist* was updated.

Significant events during the financial year included investment in a desktop publishing system for *Trail & Landscape* and the publication of a special publication titled *Lichens of the Ottawa District*. An unusual event regarding the 1987-88 Financial Statements was that the audit was not finished before the Annual Business Meeting last January. The Meeting approved the financial statements, subject to a satisfactory report from the auditor, which was received shortly afterwards.

FRANK POPE (Chairperson)

Macoun Field Club Committee

The Club continued its active program for young people in 1989. Saturday morning meetings for Juniors (Grades 4-6) and Intermediates (Grades 7-8) alternated weekly with Saturday field trips. Seniors (Grades 9-13) met weekly on Friday afternoons. In May, a bus trip to Charleston Lake was made possible by a donation from the Excursions and Lectures Committee. Volume 43 of *The Little Bear* and a monthly newsletter were produced by Senior member Lorin Gaertner.

During the 1988/89 school year, leadership came from Rob Lee and Joe Shepstone. In recent years the Club has tried to move away from relying on a single individual for leadership, towards a more diffuse leadership organized

1989 Paid-up Membership in the OFNC

Type	Canada		Foreign		Total
	Local	Other	USA	Other	
Individual	482 (471)	214 (202)	43 (47)	6 (6)	745 (726)
Family	351 (315)	29 (24)	1 (1)	0 (0)	381 (340)
Sustaining	15 (33)	0 (2)	0 (0)	0 (0)	15 (35)
Life	16 (16)	17 (18)	4 (3)	2 (2)	39 (39)
Honorary	16 (16)	6 (7)	1 (2)	0 (0)	23 (25)
Total	880 (851)	266 (253)	49 (53)	8 (8)	1203 (1165)

through the Committee. Since September (1989/90 school year), responsibility for organizing meetings and field trips has been shared among many members. The Committee is now more active than it has ever been in the Club's history.

BARRY BENDELL (Chairperson)

Membership Committee

The total paid-up membership as of November 27, 1989 was 1,203. One hundred and sixty-two new members joined the Club this year. Assuming an average of two members per family, the total membership served by the Club is estimated to be 1,584.

The following chart summarizes the membership distribution. The figures in brackets are the 1988 totals. Volunteers listed with the Club number 102. Many of these people were approached for their assistance by the various Club committees.

The Membership Committee and the Excursions and Lectures Committee once again co-hosted a very successful New Members' Night on November 10. Approximately 90 people, including several honorary members and members of Council, enjoyed wine, cheese and other refreshments in the Salon of the National Museum of Natural Sciences.

KAREN RICHTER (Chairperson)

Publications Committee

This Committee oversees and advises Council in the Club's publications. Only one issue of the *Canadian Field-Naturalist* was published in 1989: Volume 102 Issue 4, containing 184 pages, 19 articles, 14 notes, 29 book reviews and 140 new titles. This publication slowdown was due largely to the restricted amount of time the editor could apply to the journal and to a lesser amount of clerical assistance than heretofore. The Committee hopes to get the *Canadian Field-Naturalist* on track in 1990.

The publication of the 200 pages of Volume 23 of *Trail & Landscape* marked the end of Joyce Reddoch's tenure as editor. She has been associated with *Trail & Landscape* since its beginning 23 years ago. On behalf of the Club, we extend thanks to Joyce for this service and especially for her superlative ten years as editor. Elizabeth Morton has been appointed as the new editor. To assist her and to make her task less time consuming, the Club has provided her with a desktop publishing system. We eagerly await the appearance of her first issue of Volume 24.

Many people are involved in one way or another with the publication of these two journals, and the Committee extends thanks to all of them.

RONALD E. BEDFORD (Chairperson)

Book Reviews

Zoology

An Odyssey in Time: The Dinosaurs of North America

By Dale A. Russell. 1989. National Museum of Natural Sciences and University of Toronto Press, Toronto. 239 pp., illus. $45.00.

This book will appeal strongly to two groups of people: those in search of a truly handsome coffee table book with a wealth of beautiful pictures; and those with considerable prior knowledge of Mesozoic reptiles who want an authoritative, up-to-date, non-technical summary of the subject. The latter group will relish the text, which is not illustrated.

This assertion will surprise anyone leafing through the book for the first time. But the fact is the pictures merely decorate the text, they do not illustrate it. I have never before seen a book in which text and pictures were so loosely coupled. Nowhere in the text is the reader asked to see Plate so-and-so; indeed the pictures are unnumbered, and the legends so terse as to be meaningless.

The pictures are of five kinds. There are 15 paintings of living dinosaurs in their habitats, by Eleanor Kish; each occupies a whole page or a two-page spread, and segments from them are repeated, for no apparent reason, in the text. There are numerous scenes of famous fossil sites, such as Horseshoe Canyon near Drumheller, and the shores of the Minas Basin in Nova Scotia; the legends list the geological formations exposed in these scenes, but prior knowledge is necessary if one is to distinguish the named strata. There are photographs (with no scale markers) of imbedded fossils and fossil tracks. There are a number of "pretty pictures", e.g., a sunset in Indonesia, and a herd of elephants in Zambia; why these pictures appear is a mystery.

Lastly, there are maps, which are even more mysterious. They are outline maps of various regions, overprinted with multicoloured mosaics. The meaning of the colours is unexplained; no doubt the blues are water, but the yellows, oranges and browns are evidently not contour layer colours; what are they? The maps bear no names and none of the places mentioned in the text are shown on them.

Maps to illustrate the text are sorely needed. The text emphasizes geography; for instance, page 37 tells us how, 225 million years ago, the earth's crust shifted along geologic faults extending from New Brunswick to Morocco, causing a rupture between North America and West Africa; an arm of the Mediterranean advanced westward over northern Africa. Submarine salt deposits formed which now persist in Newfoundland and Nova Scotia; crustal sinking produced rift valleys stretching from Alabama to Nova Scotia. On the same page is a brightly coloured map of the southwestern USA!

To enjoy the text, therefore, the reader must have other books on hand. A recent discussion of plate tectonics, illustrating how the continents and oceans have changed since Permian times would be helpful. Also, an introductory guide to dinosaur history that includes some sort of family tree (this book has none); a diagram showing the anatomical difference between the bird-hipped and the lizard-hipped dinosaurs (there isn't one here). And line drawings to illustrate the Triassic therapsids and sauropsids here given such embarrassingly whimsical names as "cowturtles," swinelizards," "owliguanas," and "wolf-crocodiles;" these, too, are left to our imagination. Only 17 dinosaur species are actually portrayed in Kish's magnificent paintings.

E. C. Pielou

RR 1, Denman Island, British Columbia V0R 1T0

The Nature of Birds

By Adrian Forsyth. 1988. Camden House Publishing, Camden East, Ontario. $29.95 (hard cover), $19.95 (soft cover).

Birds have a special place in our hearts. We only have to reminisce about the deep feeling of intimacy with nature triggered by the long and modulated complaint of the Common Loon or by the flutelike song of a Hermit Thrust. We, as humans, perceive birds differently than we perceive other vertebrates. Poetic notions of freedom, love, and beauty always spring to mind when we think of them. In this book, Adrian Forsyth gives a more rational perspective of the nature of birds. In a series of lively and nicely written essays, he demystifies the scientific work of professional ornithologists and, as a consequence, diffuses part of the romantic aura we attach to birds.

The text is abundantly illustrated with stunningly beautiful colour photographs which only confirm what we already know about birds: they are the most photogenic of all vertebrates.

Good scientific work has little to do with our romantic perception of birds. In fact, the scientific literature on birds is about as poetic as a phone book. Why is this so? Simply because any scientific

quest is always a long, arid, and tortuous process. Often, ornithologists devote their whole career to the understanding of the behavioral and ecological intricacies of one species. Hypotheses dealing with the adaptive value or the evolution of a particular trait (behavioral, ecological, etc.) are often accompanied by complex mathematical models which are verified by field or laboratory work over several years. Lengthy technical manuscripts filled with results and interpretations are submitted to renown scientific journals only to be severely criticized by peers and, often, simply rejected. Since the policy of "publish or perish" is at the core of the process of scientific recognition, there is very little incentive for scientists to popularize their work. Moreover, scientists are often poor communicators. They have a tendency to isolate themselves in their own little world of specialized research and are often detached from the more basic preoccupations of the general public.

Ornithology has suffered from this situation in the last decades. The communication gap between professional and amateur ornithologists has widened steadily. This book is a honest attempt to bridge this gap. The twelve essays are beautifully structured and provide a good mixture of personal observations examined with the added light of current findings in scientific circles. A special attention is given to the evolutionary significance of various behaviours (singing, mating, territoriality, nesting, feeding, etc.). The essays are short but the essence of each subject is clearly presented. For example, the reader will be curious to know the adaptive significance of such behaviours as infanticide or cuckoldry for certain birds. All the discussions are interesting and enlightening as they try to explain each feature of a bird in terms of the reproductive success it confers to its bearer (i.e. production of offspring that will ultimately reproduce). However, the idea that *everything* a bird does is related to its reproductive success is a bit farfetched and will certainly ruffle the feathers of several scientists.

The last two essays are more philosophical in nature. They deal with urgent conservation issues and the importance of communication between scientists and amateurs.

Overall, I consider this book as a worthwhile acquisition. When I first opened it, I quickly leafed through it and marvelled at the beauty and quality of the photographs. Now that I have read the book I think that everybody interested in birds will learn something significant. The amateur will know more about current ideas underlying the various fields of research in behavioral ecology and the scientist will have a high quality first-hand lesson on the popularization of scientific concepts.

FRANÇOIS CHAPLEAU

Department of Biology, University of Ottawa, Ottawa K1N 6N5

Polar Bears

By Ian Stirling. 1988. the University of Michigan Press (Canadian distributor Fitzhenry and Whiteside, Markham, Ontario). viii + 220 pp., illus. $55.

Polar Bears, the seals they eat, and the Arctic marine environment have dominated most of Ian Stirling's working life. Canada's premier Polar Bear biologist combined his experience, knowledge, and understanding of the polar world to write an erudite but readable account of the "Arctic incarnate". Stirling has organized his book around two general themes. First, the Polar Bear does not exist in isolation because it is a product of, and part of, the polar marine ecosystem. In the context of the first theme, Stirling examines how Polar Bears survive in a dynamic environment and the importance of the Polar Bear to the cultural and spiritual bliefs of the indigenous people who share the polar world with this species. Second, the Polar Bear is an individual, a solitary predator thriving in an extreme environment. In accordance with this theme, Stirling examines its behaviour in relation to its environment, to its prey, and to man.

In Chapter 1, Stirling traces the evolution of this species from the Pleistocene to the present. He examines how the Polar Bear evolved from the Brown Bear and describes some of the characteristics which contribute to its ability to thrive as a polar marine animal. For example, the entire animal is covered with hair except for the nose and foot pads, the fur is white, the teeth are smaller and more jagged than the Brown Bear for life as a carnivore (the canines are larger and sharper for tearing seal flesh), and the claws are shorter and more solid than those of the Brown Bear.

In the second chapter, Stirling traces the coevolutionary relationship of the Polar Bear and man beginning with the Paleoeskimos. He reviews Inuit spiritual beliefs and practices as they relate to the Polar Bear, Polar Bear legends, and provides a brief account of the European explorers who were generally insensitive to the polar world around them, and who killed numerous bears for no useful purpose. Stirling ends the chapter on an upbeat note about the useful work of the modern polar scientists.

In the next chapter, entitled "How Do You Study A Polar Bear?", the reader learns about some of the techniques employed to immobilize and handle Polar Bears, whether or not handling bears affects them, when to study the Polar Bear, and what information is required for their conservation. The logical extension of this chapter is a review of the distribution and abundance of this species in relation to habitat (principally sea ice), seasonal changes in distribution, movement, home range, and subpopulations. In his review of home range and subpopulations, Stirling dispels the myth that the Polar Bear wanders randomly throughout the Arctic. He ties this biological information into a discussion of management programs.

Chapter 5 is devoted to reproduction, including breeding behaviour, denning, growth of cubs, age of maturity, and litter size. Stirling follows with a chapter on behaviour, and nicely summarizes what we know of Polar Bear behaviour with a review of seal hunting in summer and in winter. The next chapter, entitled "Life and Death", provides insight into the mortality of cubs and subadults, the longevity of adults, and the influence of hunting on Polar Bear populations.

Throughout the book, Stirling successfully endeavours to describe the Polar Bear's world and the variety of factors that contribute to its ability to thrive in the marine polar environment. This discussion is rounded out in his chapter on physiology, which examines body temperature, digestibility of Ringed Seals, hibernation and energy conservation, and the physiological effects of oil on bears.

The remaining chapters are focused on research conducted over a 20-year period beginning in the mid-1960s at Churchill, Manitoba, and vicinity, conflicts between Polar Bears and humans, and conservation and environmental concerns which are being addressed in some of the management programs. Stirling talks of habitat protection, of environmental threats such as habitat modification, and of the impacts of toxic chemicals. He ends the book with a statement about the management of hunting and environmental issues in the polar world.

The book is a must. Stirling accomplished his goal of writing "a popular but scientifically accurate account of the polar bear". The photographs accompanying the text are magnificent; some of the finest I have seen. They capture this stately species in its natural environment, and in areas modified and inhabited by man. Quiet frankly, I expect that they will leave the reader awestruck. Unfortunately some of the photographs are not captioned. The text is punctuated with maps and tables. The appendix contains the "International Agreement on Polar Bears and Their Habitat", and a copy of the "Management Agreement for Polar Bears in the Southern Beaufort Sea". The book contains a short bibliography and an index.

PAUL A. GRAY

Wildlife Branch, Ontario Ministry of Natural Resources, Whitney Block, Queen's Park, Toronto, Ontario M7A 1W3

The Natural History of Squirrels

By John Gurnell. 1987. Facts on File, New York. 232 pp., illus. U.S. $21.95; $31.95 in Canada.

At least 264 squirrel species inhabit the Earth, according to figures in John Gurnell's book; 143 are classified as tree squirrels, 83 as ground squirrels, and 38 as flying squirrels. To describe the natural history of this diverse group in a small volume would be a monumental task. Gurnell does not attempt to do this. Instead, he provides an overview of the biology and ecology of Holarctic tree squirrels of the genera *Sciurus* and *Tamiasciurus*. Tree squirrels are the only squirrel taxa of Great Britain, the author's homeland, and, unless you live on the prairies or tundra, are probably the most familiar of squirrels. In writing this book Gurnell builds on the familiarity of the squirrels to naturalists and the public to provide greater understanding of these common animals.

This is among the latest of a British-based series of natural history books on mammals edited by Ernest Neal — a past president of the Mammal Society. As with other titles in the series (e.g. badgers, otters, antelope), the author's scientific interest heavily influences the focus of the book. Of the 10 Holarctic tree squirrel species, six receive the most attention: grey, fox, douglas, abert, red (*Sciurus vulgaris*), and pine (*Tamiasciurus hudsonicus*). Gurnell has research experience with pine squirrels and Britain's red and introduced grey squirrels, and with other small mammals of Britain.

Equal space is devoted to chapters on food and feeding, activity and energetic, space-use and social organization, population dynamics, community ecology, interrelations with humans, and description, homes and habitat. The chapter

on squirrels of the world is significantly smaller, while tree squirrel behaviour, of particular interest to the author, is covered in more detail.

A major asset is the inclusion of 80 tables, figures, and line drawings which depict and elucidate tree squirrel life history. On several occasions the author summarizes reams of data into useful tables to compare life history traits between species. These tables include sex ratios, territory size, development of young, energy requirements, and energy contents of foods. Gurnell includes his own previously unpublished data in some of these summaries. Some of the figures needed better descriptions to stand on their own and the few maps included were not particularly well done, but on the whole they are valuable resources. Twenty colour photos of eight squirrel species are inserted in the middle of the book, but I found no reference to them in the text.

While tending towards the academic, the book is also well written for the general reader. Gurnell does a good job of pulling together information from both North American and Eurasian sources, but at times the summaries resemble the compilations found in *Mammalian Review* — informative, but a bit dry for the general reader. His emphasis on providing large amounts of facts at times detracts from his flow of ideas. Some information is repeated and there are a few inconsistencies. For example, he states that dispersing animals that do not successfully establish a territory "will starve to death"; later he says there "is very little good information about squirrels actually dying of . . . starvation." Typographical and editorial errors exist, but are few. A few cited papers are not included in the bibliography.

Gurnell provides good overviews of the topics covered and minimizes editorial commentary. He often includes a description of field study techniques of interest to students or naturalists. Interesting tidbits of squirrel trivia abound. We learn that grey squirrels are either right- or left-handed or that they will cut out the seed embryos from white oak acorns to kill them and prevent them from germinating where they have been cached. I was particularly intrigued by the ongoing debate on the impact of the introduced grey squirrel on Great Britain's congener the red squirrel. I found his discussions confusing at times, though, as he regularly attributes facts to "squirrels", making it necessary at times to glance back to determine which squirrel(s) he is describing.

In the Foreward the series editor states that this book will allow readers from many parts of the world to learn about their own more familiar squirrels in a much wider context. This has been done to a limited extent. Gurnell has left room, though, for further editions on ground squirrels, flying squirrels, and even perhaps other tree squirrels. The limited reference to tropical tree squirrels is a particular drawback considering the growing biological literature from tropical habitats and the growing public interest in tropical forest conservation.

Given its limitations this is still a good natural history book on *Sciurus* and *Tamiasciurus*, whose cumulative ranges cover much of the Northern Hemisphere. I would recommend it to anyone interested in a reference book on these species.

MARK STABB

R.R. 1, Baysville, Ontario P0B 1A0

Familiar Amphibians & Reptiles of Ontario

By Bob Johnson. 1989. Natural Heritage/Natural History Inc., Toronto. 168 pp., illus. $9.95 + $2 postage.

This book is written as a guide to the identification and behaviour of Ontario amphibians and reptiles. A few rare species with very restricted ranges in the province have been omitted. Otherwise, the book is complete, with descriptions of ten salamanders (including Red-spotted Newt), eleven frogs and toads, eight turtles, fifteen snakes and one lizard (the Five-lined Skink). Each description includes physical features, habitat and natural history.

Amateur natural historians will welcome the book as an enticing introduction to a relatively inconspicuous and often misunderstood fauna. It is highly readable, with a minimum of taxonomic detail. Animals are grouped by class and order, but family groupings are not mentioned. Latin roots and their meanings are given for all the scientific names (class, order, genus and species), allowing the reader to easily associate the descriptive Latin name with the distinguishing features of an animal. Common names are given in both English and French.

Each species account includes two range maps: one of Ontario showing the details of provincial distribution; and the other of North America to show the overall species range. Thus, it is readily apparent which species are truly restricted in range, and which are marginal in Ontario but widespread elsewhere. This is particularly important since many species reach the northern limit of their range in southern Ontario.

The emphasis of each species account is on natural history and behaviour, and on these topics

the book excells over most other field guides. Periods of hibernation, emergence, breeding, egg-laying, hatching, and larval transformation are defined for Ontario populations. Courtship rituals, aggressive displays and other interesting aspects of animal behaviour are frequently described, often with amusing anecdotes based on the author's personal experience.

Some interesting aspects of natural history are conspicuous by their absence from the discussion (e.g., neoteny in mudpuppies, mechanisms of orientation in spotted salamanders, aging and growth annuli in turtles, how to sex snakes, their specialized jaw apparatus, scent trailing, and caudal display in ring-neck snakes). However, it is impossible to provide comprehensive natural histories of all species in a field guide format. There is enough natural history to wet the reader's appetite for more.

The illustrations are not in colour and are sometimes lacking in diagnostic detail. However, the text compensates with a verbal description of key identifying features for adult and juvenile animals. Larval amphibians are not described sufficiently to permit identification; however, such microscopic detail would not likely be appreciated by general readers.

In summary, the book is well written, informative and likely to stimulate the amateur natural historian to a keen interest in Ontario herpetofauna.

DONALD R. HART

Beak Consultants Limited, 14 Abacus Road, Brampton, Ontario L6T 5B7

Handbook of North American Birds, Volumes 4 and 5: Diurnal Raptors

Edited by Ralph S. Palmer. 1988. Yale University Press, New Haven. Volume 4: vii + 433 pp., illus.; Volume 5: v + 465 pp., illus. U.S. $80.00 set.

These two long-awaited volumes continue a series that commenced in 1962 with a volume on loons, grebes, totipalmate swimmers, the heron-ibis-stork group, and flamingos. The second two volumes, on waterfowl, appeared in 1975. They are essentially a modern version of A. C. Bent's series on "life histories" of North American birds (1919 to 1968), but their slow rate of publication suggested that many decades would have passed before the series was complete, at least if continued in the same manner. At present, there are no plans to continue this series in its current format, although a planned series of "bird biographies" will partially fill the same function.

These volumes cover all species of diurnal raptors (Families Cathartidae, Accipitridae and Falconidae) reported to occur in North America "north of Mexico," but including Baja California. The Osprey is included within the Accipitridae, in agreement with the most recent checklist of North American birds. Although Hawaii is included in many North American avifaunal works because of its political affiliation, it is not North American biologically, and not covered here. Volume 4 consists of an introduction to both volumes, species accounts of North American vultures, Osprey, Bald Eagle, sea-eagles, Northern Harrier, and hawks of the genera *Accipiter, Buteogallus, Parabuteo,* and *Asturina* (including the Red-shouldered Hawk), and an index. Volume 5 consists of hawks of the genus *Buteo,* Golden Eagle, Crested Caracara, and the falcons, an index, and a composite list of literature cited in both volumes.

Accounts of species that normally occur in North America for at least part of the year range from seven (Hook-billed Kite) to 55 pages (Peregrine) in length and cover descriptions, field characteristics, distribution, migration, numerous aspects of behaviour and biology, banding status, conservation topics, and sometimes other subjects. These accounts are North American in emphasis, but use data from throughout the species' range when appropriate. Species that have been substantiated as occurring in North America but are not regular here receive a condensed treatment of one to three pages. Two species (Eurasian Sparrowhawk and Common Buzzard) for which there were only unsubstantiated North American records are mentioned in a one-paragraph footnote each.

Palmer personally wrote many sections, and sometimes entire species accounts, but many have been co-authored by experts on the species, including Canadian residents David M. Bird, Jonathon M. Gerrard, and J. Bernard Gollop. Although initial drafts of most accounts were complete in 1981, Palmer has managed to incorporate most significant new material that appeared in major journals to about early 1986 into the text, and even mentions the extinction in the wild of California Condors, as of 19 April 1987, in his introduction.

A comprehensive account of all diurnal raptors in North America is nearly an impossible task in the 1980s, considering the rate at which new information becomes available — for example, Palmer states that over 1200 significant sources on Red-tailed Hawks exist, of which he was able to

scan 550 and cites 135, while he consulted 700 sources on Golden Eagles, and cites 242. In addition, he was aware of "at least 550 titles" of significance that appeared between the time large sections of the book were complete and the volumes were ready to go to press. Thus, the accounts necessarily omit some details and specialists on any given species will no doubt detect some errors and outdated information. Nevertheless, both volumes are jammed with information and guide the interested reader to major works and bibliographies on each species.

Most omissions and factual errors that occurred to me as I read through the books were the result of information that has been published since 1985 or in sources that are fairly obscure. For example, Dick Dekker's 1985 book, *Wild hunters*, could have added considerable behavioural and ecological points on several species in Alberta, but would not likely be known to Palmer until reviews began to appear in journals. Apart from problems with references, proof-reading errors are also relatively scarce for the number of pages covered — I detected about 20, of which the most amusing are conifer "springs" and "mudkrat".

The writing style of such compendia is rarely conducive to casual reading, and some passages can be tedious — after all, the objective is to serve as thorough a reference source as possible. However, Palmer does manage to insert some lighter phrases, such as his reference to the Sharp-shinned Hawk as "an expert — *numero uno* — at sneak attack," and his reference to the falconry literature as "Extensive, with no end in sight" or in his account of the Peregrine, "that most popular and most Propagandized of all raptors." Joseph A. Hagar's long (13 pp.) account of Broad-winged Hawk migration, almost uninterrupted by references reads more like an essay, albeit authoritative, in contrast to the same author's heavily referenced eight-page account of Swainson's Hawk migration.

Space precludes a detailed review of each species account, but a few highlights, errors and omissions that I noted follow. In addition to purely biological details, ornithologists interested in the influence of birds on culture will find much of interest in these volumes, especially in the sections on symbolism, legend, etc. under the Bald and Golden Eagles and the section on falconry under peregrines.

Conservationists will find considerable detail on effects of biocides, electrocution, and persecution. Taxonomists will be interested in the separation from *Buteo* of the Gray, Roadside, and Red-shouldered hawks into *Asturina* and in Palmer's treatment of Harlan's and Krider's hawks not as races of Red-tailed Hawks, but merely as colour variations.

Outright errors are few, but Hecht's study of Northern Harrier took place in Manitoba, not Montana and Hatch's observation of Golden Eagles hunting a fox also took place in Manitoba, not Saskatchewan. Predation by Red-tailed Hawks on other *species* is incorrectly labelled cannibalism, a term correctly applied only to intraspecific predation. A one-page section on food habits of Rough-legged Hawks headed "siblicide" contains only two lines on that topic. The reference to the Turkey Vulture in the West Indies as "spotty" in distribution with no mention of Cuba is misleading, as they are among the most conspicuously abundant birds there (Wotzkow and Wiley. 1988. *Journal of Raptor Research* 22:3-7; personal observation), while the statement that the North American race of the Osprey stays there only a short time after arriving in September, based on work by Barbour in the 1940s, is outdated. The catalogue of Cuban birds published by Garrido and Garcia Montana in 1975 lists them as present from August through May, and in two winters of field work, we saw them more frequently than the resident race, at least in the Cienega de Zapata.

Jackson discusses the harm that bands do to the legs of vultures and mentions that patagial (wing) tags are now used instead, but oddly does not mention that colour markings have been shown to affect their social behaviour, even though some of the evidence for this was published in a book that he co-edited. Although Palmer discusses possible confusion between Gyrfalcons and Peregrine Falcons, he does not mention that Gyrfalcons can be confused with Northern Goshawks in flight, a point often made by raptor enthusiasts (e.g., Dekker. 1977. *Alberta Naturalist* 7:1-5), but sometimes overlooked by other birdwatchers. Whether or not earlier nesting by Great Horned Owls helps them avoid nest competition with Red-tailed Hawks, this chronology is not restricted to warmer climates — Winnipeg birders have long begun to look for the "horns" of this owl in traditional nests by mid-February.

In addition to providing a reasonably current summary of current knowledge, a vital function of this kind of work is to guide the reader to additional literature. Palmer faced a mammoth task in trying to point the way to a vast body of literature that would take another large volume just to list. He has done a credible job of this by combining all references from both volumes in one crowded section in volume five, relying heavily on major review papers where possible, omitting the titles of papers published in journals, and listing papers in symposia under the editor(s) of the symposia.

A few references are too vague to be helpful. For example, for details on the Eurasian race of Rough-legged Hawk he advises the reader to consult European literature, rather than providing a key reference or two, and in several places a good

review paper is followed by "and more recent data" or similar unhelpful phrases. A few key references are omitted — for example, the California Condor's former distribution to southern British Columbua is noted, but Wilbur's 1983 summary of its occurrence in the Pacific Northwest (*Auk* 90: 196-198) is not cited. More importantly, there are numerous disagreements between the text and literature cited on spellings of names, numerous omissions of "a" or "b" required to distinguish between two references, and at least 117 references cited in the text are not listed in the literature section.

In spite of its flaws, this two-volume work is a gold mine of information and will long be *the* place to start a search for data on any North American diurnal raptor species. Palmer and his co-authors have not only provided a detailed summary of current knowledge and an important guide to further literature, but have also emphasized points needing further research. Like the previous three volumes, these will be much consulted and much cited.

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M 1X4

Birds in Ireland

By Clive D. Hutchinson. 1989. Poyser (distributed by Buteo Books, Vermillion, South Dakota). 215 pp., illus. U.S. $55.

Ever since the Pope gave Henry VIII sovereignty over Ireland there has been strife. This is the mental image we have; promoted by endless television footage of bottle throwing youths and tear-gas lobbing soldiers. But there is another side to this troubled island. The rolling countryside, constantly washed by an encircling sea and bathed by mist and rain, really is emerald green and has a fascinating natural history. This book is about that other Ireland.

But even here there is an enigma; one the author attempts, yet never succeeds in explaining. For Ireland's mystery lies not in the birds that have been seen but in the ones that have not. Why, for example, are there so many records of North American ducks and yet not one for Barrow's Goldeneye (a bird which breeds in the much closer country of Iceland and which has occurred in nearby Britain)? Why don't the common British woodpeckers, chickadees (tits) and nuthatches breed anywhere in the Irish countryside. There are certainly enough woodlands, both ancient and reforested, to support some level of activity. The author reviews the current theories but I found none were satisfying, alone or in combination. We clearly do not understand the complex mix of factors that meet these species requirements.

The North American reader will be amazed at the number of familiar birds that occur as annual vagrants (or nearly so). Green-winged and Blue-winged teal, Ring-necked Duck, White-rumped, Pectoral, Semi-palmated and Buff-breasted sandpipers, Wilson's Phalarope, and at least a warbler or two enliven the damp Irish fall. These are joined by wanderers from eastern and northern Europe to give Ireland an impressive list of migrant rarities. The most startling entry is of a specimen of an Eskimo Curlew spotted by a very alert and knowledgeable individual in a Dublin poulterer's shop in 1870!

Ireland has some important breeding records, particularly seabirds. The author has given greater emphasis to these birds in his text, providing, where possible, colony size and temporal variations. It also has some significant wintering populations of shorebirds and geese. This gives Ireland a special position and an important responsibility in Europe. In a chapter on conservation, the author explains how the Irish have met those responsibilities and shows what challenges they now face.

The book also has explanations of the factors affecting the distribution of birds and the recent changes in status. These introductory materials serve to set the stage for the species accounts (which occupy 75% of the text). To support the data presented there is an extensive bibliography.

The author has effectively used maps, tables and histograms to illustrate key points. I particularly liked his use of histograms to show the seasonal distribution of vagrants. He has also included black-and-white photographs of the habitat at some of the important locations. Although some pictures include birds, this is not their primary intent. The bird illustrations are instead provided by John Busby. These appear in the form of field sketches, overlaid by grey washes. Although they have obviously been done quickly and simply, they show an extraordinary talent. Only one who has a thorough knowledge of the birds, plus artisic ability, could so cleverly capture with so few lines the form and movement of his subject. Those of us who try to make field sketches will undoubtedly be envious.

This book is well organized, attractively laid out, and written in a smooth and flowing style. The author has carefully chosen his criteria for the selection or rejection of information and records to give the book a good balance. Each reader should get a comprehensive and valid portrait of Ireland's birdlife from their own armchair. This is a good purchase for everyone, Irish or otherwise, and will stand as a major reference for 10 to 20 years to come.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

American Warblers: An Ecological and Behavioral Perspective

By Douglass H. Morse. 1989. Harvard University Press, Cambridge, Massachusetts. 406 pp., illus. U.S. $30.00.

Well-known for his *Behavioral Mechanisms in Ecology*, Morse is Hermon Carey Bumpus professor of biology at Brown University. Bumpus, remembered for his early studies on natural selection in English Sparrows, would no doubt approve of the present ornithological contribution. In this book, Morse provides a considered synthesis of the literature on the natural history of the some 130 species of paruline warblers. Opening with an overview of their evolutionary history, he shows why this group, with its possible origin in deciduous forest and subsequent divergence and clinal variation, is a good model group for study. An analysis of the breeding season involves the energetic costs of arrival and aspects of nesting, clutches of eggs, incubation, nestlings, and mating patterns, including attention to the annual production of eggs and conflict between individuals. Foraging in this primarily insectivorous group has been extensively studied, and is reviewed in terms of vegetative substrates, feeding specializations, sexual differences, social influences, and spatial and temporal variation of food. Based on the classic work by Robert MacArthur on niche differentiation, the examination of habitat selection highlights salient environmental features and the importance of interspecific, but not predatory, factors. The closely related topic of territorial behaviour draws in size of territory, intersexual dominance relations, philopatry, and flexibility in spatial patterns. The role of predators and parasites focuses on nest predation, brood parasitism, consequent defensive behaviour, and the wide spectrum of parasites known.

Two chapters on display and plumage cover visual displays and song in terms of their function, social and environmental contexts, and evolution of repertoires. The fascinating topic of plumage is examined for its environmental, social, and species-isolating functions as well as seasonal, ontogenetic, and sexual differences. Migration and wintering include routes of passage, orientation, and costs of metabolism, foraging, climate, predation, and competition. Wintering may be the critical period of the life cycle, influencing behavioural stereotypy and the distribution of species which breed together. Population dynamics are linked to changes in habitat, such as destruction of forests, and subsequent limitation on the breeding and wintering grounds. Competition, whose role in structuring ecological communities has been questioned of late, is concluded to be strong, as reflected in extensive habitat partitioning, especially spatially. Morse also investigates the issues of rare species, for which rarity and specialization are not always linked, and hybridization, in which usually strong specific discrimination breaks down. Under a broader view, there are comparisons with tropical warblers (with such features as bright monomorphism, mixed-species flocks, and possible competition with anole lizards) and with ecological equivalents, foliage gleaners ubiquitously found in arboreal communities in such forms as Old World sylviine warblers and neotropical tyrannids. Opportunities for further research on a number of topics draw the book to a close.

Morse has prepared an excellent review of the available material. Equally important, he has pointed out paradoxical observations (such as the loud vocalizations of fledglings), attempted resolutions of conflicting data (such as the importance of cues in habitat selection and hypotheses about hybridization), and highlighted areas where ignorance is especially large (such as the quantitative details of the reproductive biology).

Where quantification has been pursued, as in the analysis of habitat selection with principal components analysis, there is good evaluation of the methodology, as is also the case with studies using playback of songs. Given the current controversy over honesty in animal communication, a discussion of this issue in warblers would have been welcome. There are proposals for experiments on such matters as environmental plasticity and behavioural stereotypy, interactions between migrants and permanent species, and the influence of parasites. The call for further comparison of wintering distributions should be a strong lure to shivering northerners. By way of possible additions, explicit conclusions at the end of each chapter might have served well, as would have, beyond the splendid dust jacket, a few colour plates. Readers of this journal with property ravaged by spruce budworm and forest tent caterpillars may be especially interested in the role of warblers as predators. Like any diverse and rapidly evolving taxon, these birds offer strong attractions to ecologists, ethologists, and evolutionary biologists. This book provides a solid introduction to these attractions.

PATRICK W. COLGAN

Biology Department, Queen's University at Kingston, Ontario K7L 3N6

Address of 7 January 1991: Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

The Facts on File Guide to North Atlantic Shorebirds: A Photographic Guide to the Waders of Eastern North America and Western Europe

By Richard J. Chandler. 1989. Facts on File, New York. 208 pp., illus., U.S. $19.95; $25.95 in Canada.

Yes, we have another shorebird book. After Hayman et al.'s magnificent and immensely detailed *Shorebirds* (see *Canadian Field-Naturalist* 101(3): 498–499, 1987) you have to wonder why anyone would attempt a shorebird book so soon. However good it is, it must have some compelling reasons for birders to spend their money on it. And surprise, there are several good reasons to buy this book. First, the book is illustrated with photographs. I don't intend to debate the merits of artwork versus photographs. Personally, I prefer the artist's conception for my primary reference, but I find photographs useful to confirm difficult identifications. This is particularly true for shorebirds. Artists tend to make the key field marks prominent to alert the reader to the key features. Photographs make no such allowances and a good one gives you the unvarnished truth. In this book, the author uses a series of 3″ × 2″ photographs for each species. Generally he shows three pictures; juvenile, and winter and summer adults. Unlike other photo-guides I have used, all the photographs in this book are of good quality. There aren't any fuzzy, overexposed, underexposed or poorly-positioned ones that have been used in other books.

The second good reason to buy this book is that it is small. I have taken my copy of *Shorebirds* into the field, but it is too bulky to be really portable. This new book is 5.5″ × 7.5″ × 0.75″ and can easily fit in your pocket, or into the glove compartment of your car.

This is also a good guide for those new to birding who have at last found the courage to tackle shorebird identification. For example, the author has coupled the usual line drawings of plumage pattern with identical photos of real birds. This is a fine idea, as it puts the worthwhile scientific terms into a realistic perspective. Also, the text is well written and informative, particularly when it explains the relationship of one group (such as plovers or peeps) to another. Beginners will find a lot of the group characteristics helpful in narrowing the identity of an unknown shore bird.

For the enthusiast the book's main value is that it covers all the species found in the North Atlantic to date. The book actually begins with a discussion of the number of species. Britain gets about 55 species compared to North America's 48. When these lists are combined they give a total of 72; the number of species covered in this book. It also explains why the British are so keen and so knowledgeable about shorebirds; it represents one of the main ways they can augment their tick-lists!

As befits the most recent publication, the author uses the latest in species names. Now I must change to Northern Pied Oystercatcher, Pied Avocet, Northern Thicknee, and Mountain Dotterel. The species remain the same, only the names have changed. Where there has been a recent split, as in the case of the Pacific-Golden and Gray/Black-bellied Plover group, the author has provided a good, clear account. In addition to the full-colour photographs provided in the species accounts, there is a useful section of black-and-white photos of birds in flight. The author has also included a short chapter on photography, including the use of blinds and the techniques of stalking.

So if you want to buy a neat, concise field guide, with excellent photos and good solid text, here is an appropriate choice. It will be useful to beginners and a valuable reference for the practiced. Not everything is perfect, however. This is the worst-trimmed book I have seen in years. Considering the cost of the book I feel the pages should at least be evenly cut. The binding, cover, and the paper quality are all good, so it is hard to understand why the printers could not cut straight pages.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

Dispersal in Rodents: A Resident Fitness Hypothesis

By Paul K. Anderson. 1989. American Society of Mammalogists Special Publication 9. Brigham Young University, Provo, Utah. 141 pp., illus. Price unavailable.

Society publications play an important role in scientific literature, and the present number continues a happy tradition of high quality for this series. The topic of dispersal patterns is of interest to many subdisciplines within zoology, and those of mammals have received particular attention recently (e.g. the volume by Chepko-Sade and Halpin reviewed in *Canadian Field-Naturalist* 103(4): 616–617, 1989). Anderson's book contrasts two hypotheses on dispersal in rodents, the emigrant fitness hypothesis (EFH) and resident fitness hypothesis (RFH). After an introduction to the phenomenon of dispersal and associated terminology, the author examines the former, the

idea that dispersal has evolved through the gain in fitness of emigrants. Its assumptions are laid out, the difficulty of falsifying it is explained, and pertinent results are then outlined. Contrary to the hypothesis, emigration is associated with lowered survival, and competition in the new location is generally higher than in the natal area. Emigration does not result in a better habitat or increased opportunities for mating, but instead in a delay in breeding whether the new territory is occupied or not. Genetically there is no convincing evidence that emigration produces heterotic mating or avoidance of inbreeding depression, or that there are emigration-prone genotypes. Altogether, Anderson concludes that there is no basis for the widespread acceptance of the EFH.

Turning to the RFH, emigration is interpreted as the outcome of interactions, between dominant parents and subordinate offspring, beneficial to those parents via inclusive fitness. The combination of philopatry and competition for resources makes the situation similar to that of angiosperms and their propagules. Adding habitat heterogeneity to the scenario leads to adaptive strategies of residents and emigrants which are dependent on such factors as their sex and the level of inbreeding and sex ratio in the population. Under the EFH, aggression of resident males is seen to have little effect on population growth. Resident females can be expected to exhibit mate choice and to treat sons and daughters differentially, while offspring should maximize their opportunity for philopatry. Male transiency is expected to exceed that of females, and delayed sexual maturity in males at the end of the breeding season could enable the accumulation of physiological reserves.

The major portion of the book tests the RFH against available data. As expected, site tenacity, philopatry, discrimination (among relatives, associates, and transients), cohesiveness of kin (especially between mother and young and between siblings), and mating preferences by females for familiar, established males are all found. The extent and importance of inbreeding is unclear, amid a complexity of findings and interpretations. High levels of aggression indicate male competition for copulations, and resident males appear generally neutral toward offspring. Among females, competition and aggression is cyclic and important for the acquisition of resources. Nepotism by resident females toward daughters is widespread, as is resistance to immigration by residents. Under the RFH, inherently philopatric young are forced by aggressive stimuli from parents to adopt a peripheral status or to emigrate.

With this considerable support for the RFH, the two hypotheses are compared in the final section of the book, with emphasis on critical aspects such as dispersal distances, philopatry, and sex bias in emigration. Possible behavioural and ecological (including demographic) tests are proposed and specific predictions, especially conflicting predictions under the two hypotheses, such as expected genotypes and the dynamics of emigration as a function of population density, are tabulated. The text is accompanied by the remarkably low tally of four tables and two figures, referencing is thorough, and there is a brief subject index.

Anderson has prepared a readable, succinct, and well-organized argument. Its importance is the suggested replacement of a dominant interpretation of a major phenomenon with quite a different one. Ascendant adaptationism, in which each major biological trait is viewed as optimized by natural selection, is giving way to other, more complex interpretations. In this regard Anderson's suggested replacement is perhaps indicative of the change from viewing every phenomenon as a functional adaptation *per se* to one in which it may be the consequence of other adaptations. Nonetheless, the claim that "drowning of emigrants may provide a built-in system for disposing of 'excess' individuals" reflects a lapse in this logic. Karl Popper, philosopher of science who crusades for the falsifiability of hypotheses, would no doubt enjoy the rich predictive detail of this book. Anderson provides a good critical examination of published experiments. For instance, reports, inconsistent with the RFH, of high levels of wounding after the breeding season are re-interpreted. In particular, the questionable relevance of many laboratory studies to the natural situation is considered. Under the RFH, since both sexes oppose male immigration, pregnancy block and male infanticide (both widely studied in the laboratory) should be rare, although it may enhance the acceptance of a transient female by a resident male. Similarly, confinement treatments, in which animals at high densities lack egress, predictably lead to pathological situations. The discussion deals with a number of issues of considerable contemporary interest, especially inbreeding, and appropriately indicates where additional investigation is needed. The perennial problem of measuring fitness rears its head at several points. This is a valuable monograph for mammalogists, behavioural and population ecologists, and, additionally, for the host of laboratory researchers on rodents who should examine how germane their work is to the field situation.

PATRICK COLGAN

Biology Department, Queen's University at Kingston, Ontario K7L 3N6

Address as of 7 January 1991: Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Running with the Fox

By David Macdonald. 1987. Facts on File Publications, New York. 224 pp., illus. U.S. $23.95.

This is an engaging book. The bulk of the text relates the author's extensive and varied personal experiences with the Red Fox, *Vulpes vulpes*. For 15 years, David Macdonald tracked, radio-tagged, photographed, and studied the ecology and behavior of this elusive animal, becoming a world's authority on the species. He has discovered considerable new information on their social behavior dispelling some widely-held misconceptions in the process: "In these circumstances (watching 11 foxes interact good naturedly) the prevailing wisdom on foxes as solitary animals seemed less compelling than it had been in the library." One easily catches his enthusiasm for foxes and also can appreciate the difficulties and discomforts of extensive year-round field work. The chapter "First Find Your Fox" will surely be meaningful for anyone who has struggled with the setbacks and frustrations of attempting to define and initiate a doctoral research program utilizing new techniques.

The 11 chapters are largely a narrative of Macdonald's observations, experiments, and discoveries on red foxes primarily in England. Interspersed within these chapters are 32 half-page boxes describing specific aspects of fox biology, history, and ecology. These boxes are as informative as the narrative chapters are interesting. They include level-headed evaluations of foxhunting and whether or not urban foxes are a nuisance. In the section on foxhunting, whose history goes back more than 2000 years, we learn of some of its unexpected impacts. For example, Hyde and Regent's Parks in London were established largely so that Henry VIII could hunt foxes close to home. Particularly well done is an explanation of the theory and practice of radio-tracking. Candid advice on the difficulties and effort involved in raising foxes as pets is also provided.

The book contains excellent color and black and white photographs and useful illustrations. I noticed no typographical errors.

Throughout this book, it is clear that the author knows and appreciates foxes and he writes about them in a captivating and informative manner. It is easy to get caught up in stories about his hand-reared "spies" which enabled observation of wild subjects at very close range and I suspect many readers will find it difficult to read the last page of the final chapter with dry eyes.

DAVID A. LOVEJOY

Biology Department, Westfield State College, Westfield, Massachusetts 01086

Game Management

By Aldo Leopold, with a new foreword by Laurence R. Jahn. 1986. Reprint of 1933 edition. University of Wisconsin Press, Madison. xxxiv + 481 pp., illus. $14 (softcover).

While making small talk at a social function a number of years ago, the inevitable question of occupations came up. The newly-introduced circle of acquaintances consisted of a customs broker, an auto salesman, a homemaker, our host (a travel agent), and me, at the time a doctoral candidate studying ecology and wildlife management. "Wildlife management?!?", exclaimed our host incredulously. "How can you possibly manage wildlife?"

Indeed, the prevailing attitude amongst legislators and the general public in North America until about 50 years ago was not unlike that of my bewildered host. Prior to the turn of the century, wildlife was viewed as a resource beyond human control, a fortuitous bounty to be harvested opportunistically until it was exhausted. In the first third of this century, the fledgling conservation movement began to perceive wildlife as a potentially renewable resource, a living legacy that required protection and husbandry by government agencies to ensure its survival and wise utilization. However, it was not until Aldo Leopold published his monumental 1933 treatise *Game Management* that the art and science of wildlife management was truly born.

Leopold synthesized a cogent discipline from a diverse and complex array of scientific methods, literature treatises, intuitive insights, and personal observations, and produced a classic text which still defines the basis of modern wildlife management. Very few current textbooks in the field deviate substantially from the formula established by Leopold over fifty-six years ago. Though techniques have been revised and updated, and though the scope of wildlife management has been broadened to include nongame species, Leopold's central tenets of responsible use are still in evidence: detailed knowledge of natural history of the animals; empirical assessment of population dynamics and characteristics; careful census methods; protection and improvement of habitat; establishment of clear management objectives; control of disease and predation; appreciation of

the aesthetics and economic potential of wildlife; and recognition of the need for sound wildlife policy and administration.

His empirical acumen is counterbalanced by a deep and abiding respect for the integrity of the natural environment, the celebrated "land ethic" which suffuses his writings and shapes his perspective. *Game Management* still provides a unique and unsurpassed historical overview of the evolution of wildlife management and the conservation ideal, from scriptural passages in Deuteronomy 22:6 to the author's own thoughtful insights on "man's proper relation to the fruitfulness of the earth".

In the author's own words, *Game Management* aspired to a three-fold function: "First, to serve as a text for those practicing game management or studying it as a profession. Second, to interpret for the thinking sportsman or nature-lover the significance of some of the things he sees while afield with gun or glass, or does in his capacity as a voting conservationist. Third, to explain to the naturalist, biologist, agricultural expert, and forester how his own science relates to game management, and how his practices condition its application to the land."

That Leopold has succeeded in his goals, there is little doubt; the esteem in which his writings are held today is an eloquent testimonial to the depth and substance of his philosophy. The re-issue of this classic text, with corrections made from Leopold's personally annotated copy and a new foreword by Laurence R. Jahn, provides an opportunity for all readers to experience the practical legacy left behind by this visionary conservationist.

DAVID T. BROWN

Institute of Urban and Environmental Studies, Brock University, St. Catharines, Ontario L2S 3A1
Present address: Department of Renewable Resources (Wildlife), Macdonald College, 21, 111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0

Eric Hosking's Birds of Prey of the World

By Eric Hosking, David Hosking, and Jim Flegg. 1988. Stephen Greene Press (distributed by Penguin, New York). 176 pp., illus. price not given.

If one had to classify *Eric Hosking's Birds of Prey of the World*, somewhere between a coffee table book and a reference text would be just about right. There is no question that Eric Hosking is one of the world's top bird photographers and it readily shows in his latest volume on what I suspect is his favourite group of birds.

With just the odd exception, virtually all of the photographs are refreshingly new. In fact, some of the species have seldom, if ever, appeared in previous books. I was surprised that during the globe-trotting efforts of Eric and David Hosking to obtain their portraits, Bald Eagles in North America proved elusive. Perhaps trips to the east or west coast of Canada or for that matter, Alaska, where these birds are quite populous, were not possible.

As a final remark on the photographs, I did like their layout on the pages with smaller photos inset into larger ones and with the borders or background removed on others. My only criticism is an occasional repetition of similar pictures, e.g., the female hen harriers on pages 64 and 65.

As for the written information in the book, the Hoskings make it quite clear in the preface that they "are not authors" and that they "owe a great debt to Dr. Jim Flegg for writing such a responsible text". Essentially, the book offers seven chapters including an introduction to raptors, a description of their physical adaptations and the hunting skills derived from them, a section oddly entitled "Birds of Prey the World Over", portraits of some of the members of the different families of birds of prey, separate discussions are provided of conservation, falconry, and, finally, a complete list of all the species in the world and their distribution. Added onto the portrait chapter in peculiar fashion (perhaps due to an abundance of good photos of these birds) is a special section on Australian birds of prey. Some suggested supplemental texts and a much appreciated index round things out.

Overall, the text is a little sparse, but this may be a function of the objectives of the Hoskings in producing the book. There is a nice balance of information though, with much of the material being up-to-date for 1987. The lengthy treatments of some species, e.g. sparrowhawk, reflect the availability of information on them.

In terms of conservation, more information on the success of captive breeding and release programs, as well as the mushrooming interest in raptor rehabilitation and public education could have been addressed. Even a list of important centres focusing on raptors in the various countries would have been welcomed.

The information on longevity on page 15 was quite misleading. Flegg gives the impression that even wild raptors are quite long-lived, when in fact, the average lifespan for the tiny American kestrel, as an example, has been shown by banding studies to

be roughly two years. I cannot agree that *Falco sparverius* is "undistinguishable" from *F. tinnunculus*, having worked with both species in captivity.

While there were very few typographical or spelling errors, one could take issue with Flegg's use of outdated names, e.g. monkey-eating eagle is now Philippine Eagle.

Finally, I cannot comprehend why owls (see discussion on page 10) are not regarded as "birds of prey" or for that matter, "raptors". Flegg is not the first author to claim this, but the reasoning, if any, makes little sense to me.

Overall, I found this book to be informative and most certainly, pleasing to the eye. It is definitely a big step up from a coffee table book and worthy of inclusion in any birdlover's library.

DAVID M. BIRD

Raptor Research Centre, Macdonald College, Ste-Anne de Bellevue, Quebec H9X 1C0

L'exploitation commerciale des poissons-appâts (ménés) dans la région de Montréal

Par Jean-René Mongeau. 1985. Rapport technique du Ministère du Loisir, de la Chasse et de la Pêche no. 06-37. Gouvernement du Québec, Montréal. XIII + 139 pp., 32 figs. Gratuit.

Ce rapport technique est le résultat d'une enquête menée auprès de 96 pêcheurs commerciaux de poissons-appâts de la région de Montréal durant l'hiver 1979-80 à l'occasion du renouvellement de leurs permis d'exploitation. L'étude se divise en sept chapitres. Le premier chapitre présente le sujet tandis que les six autres chapitres traitent de: i) la réglementation de l'exploitation des poissons-appâts; ii) des méthodes d'opération des pêcheurs, c'est-à-dire la capture, le transport, et la conservation des poissons vivants; iii) de la démographie des détenteurs de permis; iv) des quantités de ménés exploitées annuellement; v) des sites de pêche et des espèces capturées, et finalement; vi) des problèmes associés à cette pêcherie. Le but de cette étude était de rassembler les renseignements pertinents à l'élaboration d'une politique de gestion de cette pêcherie.

Les lecteurs seront certainment surpris d'apprendre que la pêcherie des poissons-appâts dans la région de Montréal s'élève à près de 100 tonnes métriques annuellement pour une valeur de plus d'un million de dollars. Sept espèces comptent pour plus de 90% de cette récolte (le Méné jaune, *Notemigonus crysoleucas*; le Méné d'argent, *Hybognathus nuchalis*; le Méné émeraude, *Notropis atherinoides*; le Queue à tache noire, *N. hudsonius;* le Méné à nageoires rouges, *N. cornutus*; le Meunier noir, *Catostomus commersoni*; et le Mulet à cornes, *Semotilus atromaculatus*). Il est à noter que Mongeau emploie méné au sens large du terme, c'est-à-dire petit poisson, et non dans son usage restrictif qui s'applique aux membres de la famille Cyprinidae exclusivement. De plus, on apprend que les poissons-appâts valent en moyenne 12 fois plus le kilo que les poissons d'importance commerciale tels l'Anguille d'Amérique, la Barbotte brune, l'Esturgeon jaune, et la Perchaude.

Cette étude intéressera principalement les gestionnaires des pêcheries, mais aussi tout ichtyologue, naturaliste, ou pêcheur à la ligne qui désire en connaître davantage sur les aspects économiques de l'exploitation commerciale de ces poissons qu'on appelle communément ménés.

CLAUDE B. RENAUD

Section d'ichtyologie, Musée canadien de la nature, Ottawa, Ontario K1P 6P4

Extinct Birds

By Errol Fuller. 1987. Facts on File, New York. 256 pp., illus. U.S. $35 (no Canadian rights).

Since 1600, at least 75 individual species of avifauna have become extinct on this planet. Not since Walter Rothschild's pioneer book carrying the same title, *Extinct Birds* (1907. Hutchinson: London), has there been such a detailed and comprehensive book on extinct birds.

Errol Fuller has spent many years accumulating information that has slowly shaped this most fascinating book. Discussed in it are all of the species of birds that have vanished since the start of the fifteenth century. Extinct subspecies, rare and endangered species, as well as obscure and hypothetical species are all discussed in this book, making it a very complete reference.

All of the species are discussed in great detail, from the mysterious Tahitian Red-billed Rail, *Rallus pacificus*, known from only a single painting, to the well known and well documented Passenger Pigeon, *Ectopistes migratorius*. These surprisingly intriguing accounts vary in length, depending on the amount of information known. They cover the history of the bird since its discovery by man, as well as its life history, when obtainable, frequently taken from the notes and

journals of the early explorers themselves. All is written in a remarkable style that keeps the reader looking ahead for clues as to what comes next.

The species accounts are divided into 17 chapters which follow a brief forward by The Hon. Mirian Rothschild. Each chapter contains one or more orders of birds. An overview of the order(s) commences each chapter, written in paragraphs also containing detailed, but brief accounts of the rare, obscure, and endangered species of that order. Extinct subspecies of birds are also discussed here, with tables listing all of the relevant species.

The detailed accounts of the individual extinct species follow, accompanied by colour illustrations, where possible, as well as some photographs and numerous sketches, drawings, and etchings. The majority of the colour illustrations are a delight to the eye, created by such famous artists as Audubon, Lear, Keulemans, and the author himself. Many of the plates from Rothshild's 1907 book are preserved within these pages, adding to the overall attractiveness of the book. A list of the individual species' scientific names as well as their measurements and descriptions can be found in the spacious margins beside the written accounts.

The final chapter of the book covers all of the hypothetical and mysterious extinct birds, reported by early settlers with no actual evidence (ie., skins, skeletons). Biographical notes, an index, and an extensive bibliography, listing a variety of references, are found at the back of the book.

Needless to say, I was impressed with this book and the overall writing style of the author. The vast amounts of information present in this book makes it an asset to the ornithologist, while the style of writing keeps it accessible to those more generally interested. Fuller has managed to assemble a full range of references, personal records and artwork, and transforms them into a readable, enjoyable and complete account of the extinct birds of the world.

BRUCE M. DI LABIO

62 Grange Avenue, Ottawa, Ontario K1Y 0N9

BOTANY

Wild Rice in Canada

By S. G. Aiken, P. F. Lee, D. Punter, and J. M. Stewart. 1988. Agriculture Canada Publication No. 1830. NC Press, Toronto. 130 pp., illus. $18.95 in Canada; U.S. $22.75 elsewhere.

This revision is a fine successor to *Wild-rice* by W. G. Dore (Agriculture Canada Publication No. 1393, 1969). The text has been thoroughly rewritten to embrace the fruits of two decades of research by the authors and others. Dore's acceptance of two species of annual wild rice in North America (*Zizania aquatica* L. and *Z. palustris* L.) has been amply confirmed by morphological, biochemical, and other data. These findings are clearly presented by Susan Aiken and colleagues.

Field botanists and consultants will find this a useful reference on the taxonomy and ecology of wild rice. The illustrations are crisp and the four full-page color plates of insect and fungal damaged plants add much to the value of the book to conservation biologists. The detailed discussions of harvesting should also interest most readers.

The text is mostly free of typographical errors, but the bibliographies are not. A quick comparison of 20 reprints on *Zizania* in my files revealed errors in 10 of the citations in *Wild rice in Canada*. Apparently the bibliographies did not receive the same care in preparation or proofreading that was clearly the case for the text, which reflects quite accurately the primary literature.

Double author citations of animal species are avoided except for a nematode mentioned on page 78, line 6. There is a potential for confusion on page 34 where first glance might suggest that the type specimen cited is that of *Zizania palustris* var. *palustris*, rather that *Z. aquatica* var. *angustifolia*, a synonym of the former. The volume number for the place of publication for the Asian species *Z. latifolia* is omitted on page 38 [Kew Bulletin volume 9]. The Canadian endemic "variety" *Z. aquatica* var. *subbrevis* Boivin is discussed in some detail on page 25, but was omitted from the synonymy of *Z. aquatica* where it is evidently the authors' opinion that it belongs.

The above problems notwithstanding, this is a fine scholarly work. The private rather than government publication and the inclusion of color plates probably account for the higher price than expected for a 130-page paperback.

GORDON C. TUCKER

Biological Survey, New York State Museum, Albany, N.Y. 12230

Lichens of California

By Mason E. Hale Jr. and Mariette Cole. 1988. University of California Press, Berkeley. vii + 254 pp., illus. Cloth $47.50 Can; paper $17.95 Can.

The first thing I noticed upon picking up my copy of *Lichens of California* is that the cover illustration — a spritely photograph of *Letharia vulpina*, the Wolf Lichen — has been printed upside down. Opening the book, it soon becomes evident that the University of California Press has failed the authors in other ways as well, this being an author's nightmare of ill-conceived layouts and muddy black-and-white photos. The only thing, in fact, that redeems *Lichens of California* is the unstinting excellence of its contents.

Mason Hale, a Research Scientist with the Smithsonian Institution, is in a degree lichenology's answer to Roger Tory Peterson. Over the years Hale's lectures and writings on lichens have reached thousands, and his *How to Know the Lichens* (Wm. C. Brown, 1979), is now a classic beginners' guide. The publication of a new lichen guide from Hale's pen is an event worth noting.

Lichens of California opens with a 26 page introduction containing the usual primers on the nature and economic uses of lichens, as well as on lichen structure, lichen chemistry, and how to collect and preserve lichens. More specific to the California lichens are: a brief, but helpful, sketch of the major plant communities of California; a discussion of the origins of the flora; a precis on early collectors; and a few words on rare and endangered lichens. On this last subject it is perhaps worth mentioning that nearly half the recorded crust lichens of California have not been recollected since the early 1900s.

The body of the book is divided into three sections, i.e. "Foliose Lichens", "Fruticose Lichens", and "Crustose Lichens". Within each section the lichens are arranged alphabetically, first by genus and then by species. In all, *Lichens of California* describes and presents dichotomous keys to some 103 lichen genera and 321 lichen species. Only 196 of the species, however, are given full descriptions; the rest are mentioned only in passing, either in the keys or in the species accounts. Accompanying each of the species accounts are notes on habitat, range, and, where appropriate, similar species.

The keys, which must inevitably form the backbone of any comprehensive guide to lichens, work very well in this book, especially for users having some prior knowledge of lichen morphology. In places, however, the authors have relied heavily on lichen chemistry — sometimes to the exclusion of morphological characters. In my opinion, this practice fails to acknowledge that most users would rather know what a lichen looks like than how it reacts with potassium hydroxide.

The species accounts are terse, but lucid, and in most cases present all the important diagnostic characters required for positive identification. The range descriptions, however, might have been made more accessible through the inclusion of a map naming the California counties.

Rounding out the book are: a glossary; an annotated list of suggested references; California range maps for 40 species; and an index. The glossary could have benefitted from the use of illustrations, or at least cross-references to illustrations in the text. Also, given that *Lichens of California* is somewhat avant garde in its use of newly segregated genera, the index might have been improved by consistent cross-referencing to the older, more established genus names.

Colour photographs are included for 48 species, and black-and-white photos and line drawings for a further 150 species. As already mentioned the quality of reproduction is poor, and probably less than 70% of the illustrations actually serve the user as intended. Particularly illegible are dark-coloured lichens such as *Collema, Leptogium, Melanelia, Sticta* and *Umbilicaria*. Even the best of the illustrations, moreover, might have been improved through the use of a reference to scale.

With a lichenologist of Mason Hale's calibre, the reviewer need have little concern for the technical accuracy of the contents of this book. The only important error I have detected is Figure 38 which, though labelled as *Peltigera aphthosa*, is actually *P. leucophlebia*. The name *Pilophoron* (page 158) should also, I suppose, be rewritten as *Pilophorus*. And finally, the treatments of a few species in *Cladonia, Peltigera* and *Usnea* are slightly outmoded in some regards.

A comparison with current Canadian lichen checklists reveals that roughly 75% of the lichen species treated in *Lichens of California* occur in British Columbia, while the figure is just under 50% for Newfoundland. Thus this book could in principle be useful to Canadian naturalists. Western Canadians, however, are already better served by Vitt, Marsh, and Bovey's *Mosses, Lichens and Ferns* (Lone Pine Publishing, 1988), and eastern Canadians by Hale's earlier *How to Know the Lichens*.

In their preface to *Lichens of California,* Hale and Cole argue that lichens are seldom studied by

naturalists because "there are almost no useful field guides — and in the colour so necessary to illustrate their brilliant orange and yellow hues. Where guides are available, they are often difficult for beginners because of the unfamiliar terminology and technical description. And finally, very few lichens have common names in English . . .".

For Canadians, these and other roadblocks to popular "enlichenment" have already been removed by the books mentioned above, and in comparison with these *Lichens of California* seems an unnecessarily technical work. The authors are, of course, to be congratulated for giving Californians their first semi-popular lichen guide; in Canada, however, this book will be most useful to the few dozen Canadian naturalists already conversant with the rudiments of lichenologese.

TREVOR GOWARD

Edgewood Blue, Box 131, Clearwater, British Columbia V0E 1N0

ENVIRONMENT

The Biogeography of the Island Region of Western Lake Erie

Edited by Jerry F. Downhower. 1988. Ohio State University Press, Columbus, Ohio. viii + 280 pp. Cloth U.S. $65.

The islands in the western basin of Lake Erie, between Point Pelee, Ontario and Catawba Island and Marblehead, Ohio, have received considerable attention from naturalists and scientists. For instance, over the past 20 years, several species of vascular plant new to Canada have been discovered on the northern islands. Pelee Island is known to support rare plant communities and rare reptiles and amphibians (in Canadian and Ontarion contexts). Because of this, individuals and conservation groups have spent a good deal of effort documenting these resources and refining our knowledge of their status and condition. The Ohio islands are even better known, because of the efforts of scientists, students, and collaborators at Ohio's universities and colleges, who have had the use of the resources and facilities of the Franz Theodore Stone Laboratory on Gibraltar Island. Thus, a sizeable database has developed on many groups of organisms occurring on and around this archipelago during this century. What has been lacking, prior to the publication of this volume, has been a synthesis of this knowledge.

A symposium on the biogeography of the Lake Erie islands was held at the Ohio State University on 28-31 May 1985. The papers included in this volume form the substance of that symposium. They are arranged into seven sections: setting, near-shore distributional patterns, insular patterns: plants and invertebrates, vertebrate distributions, migration and immigration, succession, and physiological ecology and genetics. A paper by Hampton Carson introduces the subject of island biogeography illustrating how geographical isolation may lead to reproductive isolation and population differentiation.

A detailed physical context for the Erie Islands is provided in the first section, in which geology, climate, and various aspects of limnology are covered. Near-shore distributional patterns are illustrated with examples from the filamentous algae, macrobenthos (aquatic insects, clams, and worms), and mollusks. Changes in relative abundance and in composition of the flora and fauna are discussed in these and subsequent articles. The theme of change is, in fact, pervasive throughout the symposium.

Several papers in this symposium do not deal specifically with the Erie Islands, but they address questions that are relevant to the biogeography of the islands or to Lake Erie's biota. The islands of the St. Lawrence River between Ontario and New York form the setting for an analysis of mammalian migration and colonization of islands. Long Point, on the north shore of Lake Erie, served as the study site for a detailed analysis of the physiological ecology of melanism in the Eastern Garter Snake. Populations of Yellow Perch from western Lake Erie and stocked reservoirs in Ohio were compared with populations from other eastern lakes.

The final section deals with the physiological ecology and population genetics of island populations, and serves to illustrate how the points made by Carson at the beginning of this book can be addressed. Even over relatively short periods of time (a few hundreds or thousands of years), populations on "islands" have become genetically differentiated. Evolution is not restricted to the classical study sites, like the Hawaiian or Galapagos Islands. Examples of microevolution from our backyard help to reinforce this fact.

Many authors have attempted to outline gaps in knowledge, or areas for future research. Although these may be specific to the Erie Islands, they should provide many ideas for biogeographic research in other regions, as well.

There are a surprising number of typographical errors in this book, especially considering the length of time that elapsed between the symposium and its publication.

The sophistication of the analyses conducted for papers within this volume varies considerably. For example, the testing of island biogeographical hypotheses with vascular plant distributional data from the Erie Islands by Klinkenberg stands in sharp contrast to the general discussions of distribution of terrestrial isopods, spiders, and small rodents. This is not intended as a criticism of the latter studies, but is meant to underline the fact that different groups of organisms are known at different levels of detail. It is also a function of species richness for each of these groups within the archipelago. As Carson pointed out in his introduction, modern analytical techniques (statistical, as well as those of population genetics) will have to be applied to biogeographical questions in future studies to determine, for example, whether or not populations of a given species are becoming differentiated from their mainland counterparts, as has been shown in a few cases already. The papers in this volume form the basis on which hypotheses may be developed, and subsequently tested, about what, how, and why the biota of the Erie Islands has developed and is changing. It is an excellent contribution to the literature on North American biogeography.

WILLIAM J. CRINS

Biological Survey, New York State Museum, Albany, New York 12230.
Present address: Geomatric International, 3370 South Service Road, Burlington, Ontario L7N 3M6

The Professional Practice of Environmental Management

By R. S. Dorney, with L. Dorney, Editor. 1989. Springer-Verlag, New York. xx + 228 pp., illus. U.S. $59.

Managing the environment is an aspect of many professions. Foresters, engineers, urban planners and others make decisions that are designed to implement some change in the area of the environment. However the ethic of ecology requires that the environment involves all inputs, all process, and all outputs. Each must be considered in planning for the future. Robert Dorney spent much of his professional life trying to put the challenge of the ecological ethic into practice in real life land use problems.

The *Professional Practice of Environmental Management* is Dorney's statement of the issues that need to be addressed by an applied ecologist. It does not teach one about any specific field of environmental studies. The book assumes that the reader is already a university graduate and is actively involved in environmental decision-making. It then goes on to discuss the many issues that need to be addressed in applying this technical knowledge to real land use problems.

This book is designed for one who wishes to live on the edge of creativity where the problems are visible but where the solutions are in a misty future. The author describes it this way: "Intuitive solutions, design solutions, public dialogue to develop solutions that are politically acceptable, just to mention a few, often irritate those who assume that rationality should dominate every problem solving situation".

Dr. Robert Dorney died while writing this book. However the thoughtful editing work by his wife and colleague, Dr. Lindsay Dorney, finished the draft into a publishable state. Robert lectured and published extensively but this book was his first attempt at bringing his ideas of the emerging profession into a coherent whole.

Dorney was a well-known scientific adventurer who aimed to understand the big picture of ecology. His taste for broad, new areas was often criticized by NSERC-funded scientists who worked on solving well-defined problems that were very restricted in scope. Dorney commented on this by stating that: "much of the academic ecology being funded with public money was if not irrelevant, at least trivial in view of the near ending or impending crises."

The difficulty in understanding ecological processes and the difficulty in getting the various branches of environmental science to understand each other are recurring themes. Dorney points out that in the last decade the ethic of ecology has resulted in government policy forcing the various professionals to work together. He wryly comments: "Suddenly engineers were thrown in with fishery and wildlife biologists; foresters eyeballed health officers and planners bolstering the sale of tranquilizers if nothing else."

The book is typical Robert Dorney. It runs in many interesting directions, all at once. Most of the time it accomplishes this task quite well.

In an effort to understand the functioning of environmental decision making the author presents many theoretical constructs. Some of these are fully

developed theories. Others are more like incomplete theorems that titillate but do not satisfy.

The 51 general principles of environmental management presented in this book are a brilliant summary of the state of the problem as defined by this emerging discipline. The principles are an enlargement of an earlier list developed in concert with Dr. Douglas Hoffman, one of Dorney's former colleagues in the School of Urban and Regional Planning at the University of Waterloo. Each principle is a gem unto itself.

These principles should be read and studied by an individual of any profession who deals with the environment. They are applicable across the broad range of environmental science and planning. I use them to provide an underlying theoretical framework for my senior students who are attempting to integrate ecological principles into recreation and parks planning.

The book is invaluable for those who wish to be or are environmental consultants. It is the only source available on many important elements of professional practice such as: study design, bidding, field studies, report preparation, presentation in front of hearing boards, legal liability, and confidentiality.

The book should be read by all government environmental personnel who hire consultants. Efficiency in the use of private expertise would be enhanced by the understanding that Dorney provides.

The book is not an easy read. It is designed for the advanced environmental scientist or planner who has post graduate education and some applied experience.

The tragedy of the author's premature death meant that the book is not as polished, as complete or as fulfilling as it otherwise would surely have been. However, it is an important contribution to the developing field of environmental management. It is the only book of its type available.

PAUL F. J. EAGLES

Department of Recreation and Leisure Studies, University of Waterloo, Waterloo, Ontario N2L 3G1

The Naturalist on the River Amazons

By Henry Walter Bates. 1989 Edition of 1863 publication. Penguin, New York. xiii + 383 pp., illus.

This book was originally published over 100 years ago. This was the time when evolutionary theory was being first introduced. Bates' experiences in South America and this book had considerable influence on Darwin's conclusions. However, the real value of this book lies in the detailed descriptions of the flora and fauna, as well as the peoples and lifestyles, of the Amazon River. We are only now realizing the importance to the world of the pending loss of much of the Amazon rain forest.

Even Bates, as described in the 1988 introduction by Alex Shoumatoff, was astounded at the destruction that was occurring when he returned to the area seven years after his initial travels. He is quoted as saying: "The nobel forests had been cut down, and their naked half-burnt stems remained in the midst of ashes, muddy puddles, and heaps of broken branches". Shoumatoff echoes this astonishment in comparing his visits of 1977 and 1984. My own Amazon rain forest experiences in 1972 emphasized, in a very short period of time, the differences between the diversity of the still forested areas and the areas along the sides of the still under construction trans-Amazon highway, with cut and burn agricultural scars everywhere. I was privileged to see the rain forest, although in the process of being settled, and to visit a native village, although artificially maintained as a tourist attraction. Even these similarities to Bates' times are few and far between, if they even exist, today.

In reading the detailed descriptions provided by Bates, this tends to further emphasize the sadness and horror of what we read is happening in the Amazon rain forest today. Bates was able to identify more than 700 species of butterfly in less than an hour's walk. At the same time there were only 321 species known from the whole of Europe and 66 from the British Isles. Now we hear estimates that over 50% of the species of the Amazon have become extinct, most before they were ever identified. Tropical forests are estimated to have over half the species of life on earth. All are undergoing similar destruction.

In 1988 alone according to the World Wildlife Fund, 1.3 million hectares of Brazilian rain forest were cut and burned to provide short-term agricultural and similar uses. The forest is being decimated at a rate of 20 ha per minute. The fertility of the area is largely bound up in the vegetation, thus disappearing into carbon dioxide when it burns. This not only results in losing the potential to renew the forest, but it also contributes to the global warming through both generation of the carbon dioxide and the loss of vegetation necessary to turn it back to oxygen.

We are often caught up in environmental problems around home. This is good, because our

high standard of living depends on the local environment. However, our continued life as a species on earth depends on a speedy resolution to the rapid loss of these tropical forests. This book is an excellent reminder of this. I would recommend that anyone concerned (and we all should be) read this and compare the vivid description of what the tropical rain forest used to be with those of what it has become today. A good photographic example of the latter can be found in the December 1988 National Geographic.

WILSON EEDY

R.R. 1, Moffat, Ontario L0P 1J0

Nature Wells Gray

By Trevor Goward and Cathie Hickson. 1989. The Friends of Wells Gray Park, Box 1386, Kamloops. xv + 190 pp., illus. Paper $9.95.

Wells Gray Provincial Park is mostly wilderness, a mountainous landscape unique in many ways. This is a book equally unique which does the park full justice with good reading, high quality illustrations, and a format demanding frequent browsing. In my experience it establishes new standards for layout and content introducing the geology, biology, and ecology of a large and wild area.

The most accessible half of the park, traversed by a road, holds abundant evidence of geologically recent vulcanism. With its cinder cones, lava flows, and other evidence of connections with Earth's molten depths, this area is, geologically speaking, among the most interesting landscapes in the province. Accounts of these features are based on the thorough explorations of co-author Cathie Hickson.

Highlights and revelations of the flora and fauna are equally well treated. The area is rich biologically, and with its several life zones ranging from a bit of steppe bunchgrass country to considerable areas of alpine-arctic heights, understandings can come only after much travel and alert observation. This is no quick regional guide among the many written following a few short hikes. Trevor Goward lives there, a naturalist in all seasons; Cathie Hickson studied the area for her doctoral thesis in geology. The authors' experience ranges throughout the region featured, and their interests extend from mountains to hot springs, from thread-like lichen in highest mountain tops to moose in the valleys bottoms, and from why the month of June is the key to the park's rain forest to an account of the insects active on the deep snows of February.

The writing is lively and briefly detailed with an unerring gift of finding the right words for explaining appearances, selected relationships, ecological processes, and biological strategies. Page layouts are imaginative with most two-page spreads having on-going text mixed with one to five other features such as photographs, drawings, maps, tables, and boxed texts on especially noteworthy subjects. It sounds confusing, but somehow it works well. In 205 pages there are 141 photographs (all black and white), 59 small marginal drawings (most of plants and animals), 54 boxed texts (many of them quotations, or direct contributions from other authors), and four maps. A full chapter deals with winter. Helpful references to best field guides are in the text, and there is a long list of major references.

This book has two outstanding values. It is a superb introduction to a unique park. It is also, in my opinion, a standard of high quality worth following when introducing living landscapes to the public.

YORKE EDWARDS

663 Radcliffe Lane, Victoria, British Columbia V8S 5B8

The River as Looking Glass and Other Stories from the Outdoors

By Craig Woods. Stephen Green Press (distributed by Penguin, New York. vi + 121 pp. U.S. $16.95.

This book is a collection of superbly written short stories about the author's experiences both as a youth and an adult. Of the stories *The River As Looking Glass* is by far the best. It is a reflection of the author's thoughts and experience fly fishing the South West Miramichi River, New Brunswick, for Atlantic Salmon. We feel his pain and agony of casting for 22 hours in the drizzle and wind without a strike, the disappointment and regret of having lost the first two fish, his self doubt, and his competitive instincts rise as family members taste success.

In all there are nineteen stories that cover a variety of experiences ranging from bass fishing as a lad, trout fishing in a small stream or on the Battenkill, walleye fishing in Quebec, or the more

philosophical question "is there a royal coachman?" On walking the woods for grouse and woodcock with his English setter one lives the experience. Woods' stories are exciting and, with the exception of two humorous tall-tales, believable. His prose awakens the senses and kindles the magic of a day in the outdoors. His book makes for delightful reading and is the next best thing to a day on the water or in the field.

GLEN BIRD

Environmental Research, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba R0E 1L0

MISCELLANEOUS

No Woman Tenderfoot: Florence Merriam Bailey, Pioneer Naturalist

By Harriet Kofalk. 1989. Texas A&M University Press, College Station. xix + 225 pp., illus. U.S. $19.95.

"Mrs. Bailey" (1863-1947) was one of America's early women ornithologists. As the younger sister of A.O.U. founder C. Hart Merriam, Florence developed an early interest in living nature, the birds and mammals of field and forest. In the 1880s, at Smith College, she led birding trips for her classmates and began her life-long commitment to conservation and the Audubon movement. She was an early advocate of bird study through an opera-glass instead of a shot-gun, and one of the first to study the "habits" of the living bird. Plagued by ill health in her youth, Florence Merriam used her periods of convalescence — some lasting for several years — to study birds, promote conservation, and write articles about them. These appeared in various newspapers and journals, including *Audubon Magazine, The Auk, Bird-Lore,* and *The Condor.* Later, she went "a-birding on a bronco" in the western United States, where the dry air of Arizona, New Mexico, and Utah restored her health and installed in her a great love for the western avifauna.

Returning to Washington, D.C., Florence lived with her brother Hart, Director of the recently established Division of Economic Ornithology and Mammalogy of the U.S. Department of Agriculture. Through her brother she met many of the outstanding biologists and conservationists of the late 19th century. Among them was Vernon Bailey, whom she married in 1899. The new "Mrs. Bailey" accompanied her husband to the American southwest. He studied mammals and she studied birds. Her field work resulted in her *Handbook to the Birds of the Western United States* (1902), which remained *the* outstanding reference book for this area for the next fifty years.

Florence Merriam Bailey continued to study western birds. When Dr. E. W. Nelson, Chief of the Biological Survey, was looking for someone to complete a book on the birds of New Mexico, begun by the late W. W. Cooke, "Mrs. Bailey" was the natural choice. More than a decade of work, surveying the literature, updating previous observations, and adding new ones based on her own field work and that of others, resulted in the *Birds of New Mexico* (1928), illustrated by Allan Brooks. The publication of her *magnum opus,* at age 65, was responsible for her being elected, in 1929, as the first woman Fellow of the A.O.U. Two years later she received the highest honour the A.O.U. could confer on any of its members, the Brewster Medal, then awarded biannually, for the most important work in ornithology of the Western Hemisphere. Bailey was only the sixth person, and the first woman, to receive the award.

Harriet Kofalk, a California naturalist, writer and poet, presents a highly readable account of Florence Merriam Bailey's life. But the evaluation of another life depends on the availability of sources *and* their interpretation. In this biography, Bailey's life is well documented in certain periods, less so in others. Thus, it is never clear, why such a keen outdoors person stayed behind in the east for several field seasons, while her husband was working in the west. Only towards the end of the book does the author hint at health problems and difficulties male scientists never have to face. There are also some minor factual errors, and occasionally a lack of understanding of the larger historical context.

In spite of these shortcomings the book will serve as an eye-opener for a new generation of scientists, whose bibliographies rarely include works written before 1950. The pursuit of ornithology, as that of other sciences, has greatly changed during the last century. Bailey and her contemporaries produced pioneering works on bird distribution, migration, life histories, and behaviour. It is high time that their accomplishments be brought to the attention of scientists and the general public alike. Additionally, Bailey's life and accomplishments, her determination to overcome illness, her work for conservation, and her many scientific achievements, as well as her concern for and continued mentoring of budding scientists, will provide a much needed role model for aspiring women scientists.

MARIANNE GOSZTONYI AINLEY

4828 Wilson Avenue, Montreal, Quebec H3X 3P2

YOUNG NATURALISTS

Animal Parenting

By Tony Seddon. 1989. Facts on File, New York. 62 pp., illus. U.S. $13.95.

Hard on the heels of last year's volumes on animal vision by Seddon and on mimicry and camouflage by Bailey (both reviewed in *The Canadian Field-Naturalist* 103(3): 473, 1989) comes the most recent contribution to this series intended for a young or general readership. As in its predecessors, a simple and vigorous introduction is achieved with a colourful and richly illustrated format. Highlighted aspects of parenting include territoriality, nest building, courtship, and nurturing, as well as more general topics such as life cycles, growth and social patterns, and embryology and ontogeny generally. Examples are drawn from a diversity of taxonomic groups and the roles of the various sensory modalities are well explicated. There is a glossary and index but no suggested further reading.

The presentation is entirely descriptive, without any reference to the vast body of contemporary theory on such issues as the origin and maintenance of sexual reproduction, differentiation of maternal and paternal roles, causes of sexual dimorphism and dichromatism, or genetic processes (such as haplodiploidy in social insects). For the most part this does not detract from the book given its intended scope, but recognition of conflict between parents and offspring makes a section headed "Happy Families" dubious at best. Beyond its value as a stimulus to budding naturalists, the book would serve as an excellent zoological accompaniment to a "facts of life" volume, especially with its family quiz and answers suitable for fireside discussion. Overall, this is an attractive work for the anticipated, young reader.

PATRICK COLGAN

Biology Department, Queen's University at Kingston, Ontario K7L 3N6

Address as of 7 January 1991: Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

NEW TITLES

Zoology

The amphibians and reptiles of Louisiana. 1989. By Harold A. Dundee and Douglas A. Rossman. Louisiana State University Press, Baton Rouge. xi + 300 pp., illus. U.S.$29.95.

Animals. 1990. By R. McNeill Alexander. Cambridge University Press, New York. c500 pp., illus. Cloth cU.S.$69.50; paper cU.S.$35.

†**Animal re-introductions: the Arabian oryx in Oman.** By Mark R. Stanley Price. Cambridge University Press, New York. xix + 291 pp., illus. U.S.$34.50.

†**An annotated list of the birds of Bolivia.** 1989. By J. V. Remsen, Jr. and Melvin A. Traylor, Jr. Buteo Books, Vermillion, South Dakota. 79 pp. U.S.$15.

***The ants.** 1990. By Bert Holdobler and Edward O. Wilson. Harvard University Press, Cambridge. 736 pp., illus. U.S.$85.

Audubon bird handbooks, I: eastern birds; II: western birds; and III: how to identify birds. 1988. By John Farrand, Jr. McGraw Hill, Toronto. 496 pp., illus; 512 pp., illus.; and 320 pp., illus. $19.95 each.

***Birding in Atlantic Canada: Newfoundland.** 1989. By R. Borrows. Jesperson Press, St. John's, Newfoundland. xii + 175 pp., illus. $14.95.

Birds of Jamaica: a photographic field guide. 1990. By Andrey Downer, Robert L. Sutton, and Yves-Jacques Rey-Millet. Cambridge University Press, New York. c128 pp., illus. Cloth cU.S.$19.95; paper cU.S.$13.95.

Cooperative breeding in birds: long term studies of ecology and behaviour. 1990. By P. B. Stacey and W. D. Koenig. Cambridge University Press, New York. c500 pp., illus. Cloth cU.S.$59.50; paper cU.S.$29.95.

Co-operative management of local fisheries: new directions for improved management and community development. 1989. Edited by Evelyn Pinkerton. University of British Columbia Press, Vancouver. c320 pp., illus. Cloth $36.95; paper $21.95.

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*The freshwater fishes of Europe, volume 1, part II: general introduction to fishes Acipenseriformes. 1989. Edited by Juraj Holcik. Aula-Verlag, Wiesbaden, Germany. 469 pp., illus. DM 236.

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*Lizards of the world. 1989. By Chris Mattison. Facts on File, New York. 192 pp., illus. U.S.$23.95; $30.95 in Canada.

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Snakes of the world, volume 2: synopsis of living and extinct species. 1990. By Kenneth L. Williams and Van Wallach. Krieger, Melbourne, Florida. U.S.$33.50. 2 volume set U.S.$59.50.

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†White bears and other curiosities: the first 100 years of the Royal British Columbia Museum. 1989. By Peter Corley-Smith. Crown Publications, Victoria. 148 pp., illus.

Zoogeography of fresh waters, volume 1: general distribution and dispersal of freshwater animals; volume 2: distribution and dispersal of freshwater animals in North America and Eurasia; and volume 3: distribution and disperal of freshwater animals in Pacific areas and South America. 1989, 1990, 1990. By Peter Banarescu. Aula-Verlag, Wiesbaden, Germany. 540 pp., illus.; 580 pp., illus.; and 350 pp., illus. 3 volumes DM 560.

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Algae of New Zealand thermal areas. 1989. By Vivienne Cassie and R. C. Cooper. Cramer (Gebruder Borntraeger, Stuttgart). 159 pp., illus.

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Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; (613) 996-1755
Assistant to Editor: P. J. Narraway; **Copy Editor:** Wanda J. Cook
Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665
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Cover: A rare occurrence of two *Bombus bifarius* bumblebees foraging from the same *Spiranthes romanzoffiana* plant, indicating the unusually high attractiveness of this orchid inflorence (*see* Larson and Larson pages 519–525). Photograph courtesy of Ron and Kathy Larsen.

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Lure of the Locks: Showiest Ladies-tresses Orchids, *Spiranthes romanzoffiana*, Affect Bumblebee, *Bombus* spp., Foraging Behavior

K. S. Larson[1] and R. J. Larson[2]

[1]1100 Ponce de Leon Circle #304 W, Vero Beach, Florida 32960
[2]Harbor Branch Institution, 5600 Old Dixie Highway, Fort Pierce, Florida 34946

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Unmarked bumblebees (*Bombus bifarius* workers) visited a 5 × 12 m patch of 12 *Spiranthes romanzoffiana* plants about every four minutes. The bees moved nonrandomly with respect to direction, zigzagging along a westerly-southeasterly path by foraging from the most "conspicuous" plants which were those with the tallest spikes and longest inflorescences. Spike height and inflorescence length were highly correlated both with the number of bee visits to individual plants and to each other. Bee visits were less influenced by the number of open flowers and the distances between neighboring plants. The bees performed nonrepeated foraging sequences 80% of the time, yet intensely revisited four of the most "conspicuous" plants. Repeated foraging sequences (20%) similarly involved many revisits to the most "conspicuous" plants. Thus, plant conspicuousness was the overriding factor that "lured" the bees to forage directionally in a patch of sparsely situated plants where revisits to the same plants occurred at higher rates than might have been optimal.

Key Words: Bumblebees, *Bombus* spp., foraging behavior, Showiest Ladies-tresses Orchids, *Spiranthes romanzoffiana*, British Columbia.

Bumblebees exploit a variety of flowers to obtain food. Floral diversity forces bees to forage in different ways. Bumblebees learn to forage (individually) by trial and error. They instinctively probe flowers for nectar but with experience become more successful (Laverty 1980). Because of the learning involved with nectar and pollen gathering, bumbleebees temporarily "major" on one flower species until a more rewarding flower is discovered (Heinrich 1976).

Studies of bumblebee behavior at flowers have been concerned mostly with optimal foraging strategies (e.g., Tinbergen 1958; Heinrich 1976, 1979a, 1979b; Pyke et al. 1977; Pyke 1978; Hodges and Miller 1981; Zimmerman 1982). Such behaviors are usually discussed in terms of their adaptive significance to the bees (i.e., optimal foraging tactics which enhance net energy intake). These include: (1) random or directional (nonrandom) foraging (dependent on flower density and magnitude of reward); (2) avoidance of recently visited flowers; (3) reduction in flight time; (4) recognition of rewards (i.e., nectar or pollen); (5) flower constancy; and (6) loyalty to a particular vicinity (Michener 1974; Heinrich 1976, 1979a, 1979b; Zimmerman 1982).

Until this report, no study has critically examined bumblebee foraging behavior on orchids. Previous pollination studies of bumblebees and terrestrial orchids of North America have stressed plant reproduction systems rather than bee behavior, partly because bee pollinators were seldom seen (e.g., Ackerman 1975, 1981; Catling 1983). This study is also the first to examine bumblebee behavior within a clump of unmanipulated, naturally occurring plants rather than between clumps (*see* Heinrich 1976).

Observations presented herein emphasize bumblebee foraging strategy at a small and isolated patch of Ladies-tresses Orchids, *Spiranthes romanzoffiana*. These orchids are widely distributed across most of Canada and the U.S. as far south as Arizona (Luer 1975), and can occur in high densities (Larson and Larson 1987). *Spiranthes romanzoffiana* is completely dependent on insects for pollination (Catling 1982). The exceptionally high frequency of bee visits to plants in our study allowed us to test the following

hypotheses: (1) that bumblebee foraging is random with respect to direction; (2) that bumblebees tend to forage between closest plants; and (3) that bumblebees avoid recently visited plants. Results herein are discussed with reference to optimal foraging theory (Michener 1974; Pyke et al. 1977; Pyke 1978), and plant morphology and distribution (Larson and Larson 1987).

Materials and Methods

A patch of *Spiranthes romanzoffiana* with bumblebee foragers (mostly *Bombus bifarius* and a few *Bombus terricola occidentalis* workers) was located at Spectacle Lake Provincial Park (48.34° N, 123.34° W) on southern Vancouver Island, British Columbia, Canada. The patch comprised twelve *S. romanzoffiana* plants situated within a 5 × 12 m area on an exposed hilltop (elevation approx. 300 m). The moss and grass-covered site was surrounded by scattered Lodgepole Pine and Douglas Fir.

The 12 plants (assigned numbers and mapped) were sparsely distributed (mean = 0.2 plants m^{-2}) and irregularly arranged (distance between adjacent plants ranging from 0.4-2.6 m) (Figure 1). Measured to the nearest 1 cm, orchid spikes ranged in height from 12-27 cm; inflorescence lengths (portion of the spike covered by flowers) ranged from 3-6 cm. The pollination state of the flowers was assessed by noting their color and shape: unpollinated flowers were white and open (2-15 per inflorescence) and emitted a slight, musty-sweet fragrance; pollinated flowers were brown and closed (0-8 per inflorescence) and were situated below the unpollinated flowers (Figure 2).

Observations of foraging insects were made on 16 August 1983 (1300-1600; 1630-1900 hrs PDT)

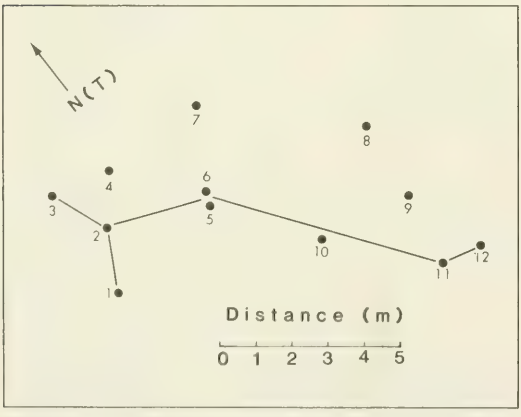

FIGURE 1. Locations of the 12 *Spiranthes romanzoffiana* plants (plant number at circle) within the 5 × 12 m study area. Lines between circles indicate the main flight path.

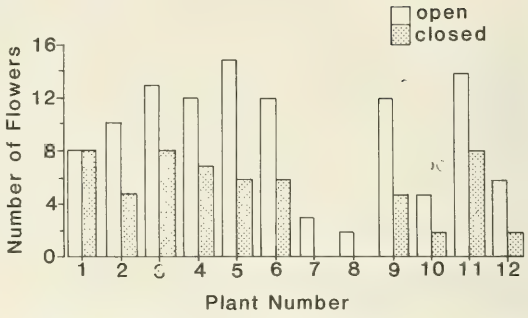

FIGURE 2. Histogram showing number of open (unpollinated) flowers and closed (pollinated) flowers per inflorescence of individual *Spiranthes romanzoffiana* plants.

and 17 August 1983 (1245-1600 hrs). Sunrise occurred at about 0600 and sunset at 1900 hrs PDT. Windless, clear skies predominated on both days, with an air temperature of 18-21°C. By sitting within 2 m of the study site, we did not disturb the foragers (*see* Heinrich 1976; Pyke 1978), and all the plants were easily seen. The area was regularly scanned for arrival of foraging insects at the flowers. When an insect was seen, it was monitored (i.e., by noting its time of arrival at a plant, its orientation and time spent on an inflorescence, and the sequence of plants it visited) until it left the study site. Individual bees were not recognizable, thus the data represents that of the population of foragers.

To determine the affects of plant proximity (i.e., *S. romanzoffiana* interplant distances) on the foraging behavior of the bees, a plot was made of the frequency distribution of the relative number of times the bees flew to plants ranked according to their nearest neighbor distances (*see* Hodges and Miller 1981; Zimmerman 1982). Chi-square analyses were used to determine the significance of the frequency distributions. Poisson distribution goodness-of-fit test was used to test for randomness.

Comparison of the frequency distribution of departure angles (i.e., departure angle = interior angle between direction of bee arrival at an inflorescence relative to direction of bee departure: *see* Hodges and Miller 1981; Zimmerman 1982) was tested using a Kilmogorov-Smirnov one-sample test.

Spearman-rank-correlation analysis was used to quantitatively compare the various factors that affected the bees' behavior. This involved using the total number of plants visited as the dependent variable tested against four predictor variables (i.e., total plant height, inflorescence length, number of open flowers, and distance to nearest plant). To further clarify these relationships, least-

squares-regression analysis of ranked data was performed using two variable sets, and the partial correlation coefficients were compared. The two sets were chosen based on the Spearman-rank-correlation matrix and contained the same variables; however, Set 1 used inflorescence length as a dependent variable but did not contain plant height and vice versa for Set 2.

Results

General foraging behavior of bees. Bees (*B. bifarius* and *B. terricola occidentalis*) foraged in an upright position by landing at the bottom of an inflorescence (where flowers were open) and crawling toward the top. They followed the spiralling flowers both clockwise and counter-clockwise, probing them with their extended mouthparts (proboscides). Occasionally, bees tried to forage upside down, from the top of an inflorescence toward the bottom; and others tried to forage sideways. The time they spent at an inflorescence varied between 5-35 seconds.

First day of foraging observations. On 16 August, when examinations of bumblebees foraging at the five most "conspicuous" plants [#'s 2, 4, 5, 6, and 11 (Figure 1)] were made (other plants were neglected owing to the preliminary nature of day-1 observations), the bumblebees made an average of nine forays (foray = time a bee was first seen in the study area until the time it left) per hour, involving an hourly average of about 25 visits (visit = each time a bee landed on an inflorescence and probed for nectar). The five plants were not equally visited: #6 (34% of total visits), #5 (28%), #2 (17%), #4 (11%), #11 (10%) ($P < 0.001$, $n = 95$).

Time between forays (= periods when no bees were seen in the study area) averaged 7 min (mode = 6 min), the minimum time being 1 min and the maximum being 24 min. Bees generally foraged in southeast and westerly directions. Plants visited twice in a single foray were #'s 2 and 6 (each 30% of the repeated visits), #4 (20%), and #'s 5 and 11 (each 10%) ($P = 0.57$, $n = 10$).

During the observations, up to three bees were seen foraging at the same time, with several instances of two bees foraging on the same inflorescence, i.e. #'s 2, 5.

Second day of foraging observations. On 17 August, when the behavior of the bumblebees (only *Bombus bifarius* was observed) foraging at all of the 12 plants within the study site was noted during a three-hour observation period, the bees made an average of 16 forays per hour (total number of forays = 50), involving an hourly average of 68 visits (total number of visits = 224). The number of plants visited per foray varied from 1-10, with an average of 4 (SD = 2).

Overall, 80% of the visits involved nonrepeated foraging sequences; yet 60% of visits were made to only four plants, i.e., #'s 2, 5, 6, 11 (Figure 3). Although most of the forays encompassed visits to different plants, some forays involved repeated visits (sometimes successively) to the same plant (up to three times).

About 20% of the 50 forays involved repeated foraging sequences, with up to three different plants being revisited during the same foray. Of the seven plants visited twice (i.e., #'s 1-6, and #11), #6 scored highest (26%), followed by #'s 5 and 11 (each 16%), and #'s 1-4 (each 10-11%) ($P = 0.74$, $n = 19$). On one occasion, two plants (#'s 2 and 5) were visited three times during a single foray.

The time between forays was random (mean = 3.7 min, mode = 4 min) ($0.75 < P < 0.90$). However, it was nearly constant from hour to hour [mean hourly averages were 3.9 min (2.5 SD), 4.1 (1.8), and 3.5 (2.6), respectively; maximum time was 10 min, and minimum was 0 min (i.e., two bees foraging simultaneously)].

During the observations, no more than two bees were seen at one time within the study area. At times, there were two bees on the same inflorescence: plant # 6 (4 times), # 2 (2 times), and # 3 (1 time), with one of the bees soon leaving.

Flight paths. The bees generally used one main flight path, flying in either a westerly or southeasterly direction (Figure 1). One tack originated from the SE at plant # 11, went towards the center plants (#5 mostly), and continued westerly to exit via plants #'s 1 or 3. The other originated from the west at plants #'s 1, 2, or 3, went towards the center plants (#6 mostly), and exited to the SE via plants #'s 11 or 12. A secondary, ill-defined path existed northwards, with entrances and exits to and from the main flight path via plant #6. Of the total forays (50), 44% entered from the west; 32% from the southeast; and 14% from the north. Those exiting

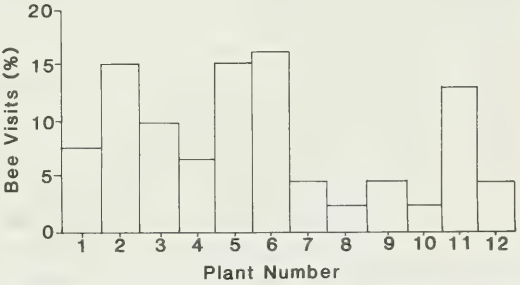

FIGURE 3. Histogram showing percent of total visits by bumblebees (n = 224) to individual *Spiranthes romanzoffiana* plants.

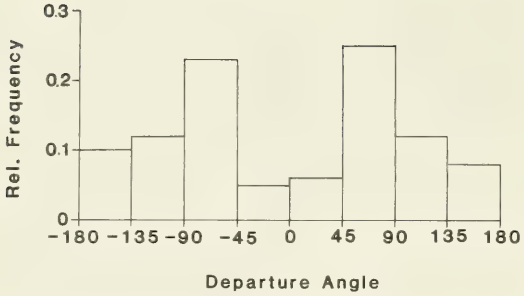

FIGURE 4. Relative frequency distribution of departure angles for bumblebees foraging among *Spiranthes romanzoffiana* plants (Kolmogorov-Smirnov one-sample test with null hypothesis being that of a uniform distribution, n = 130; $P < 0.001$; + = right turns; - = left turns).

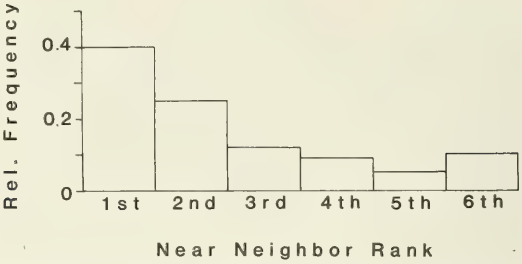

FIGURE 5. Relative frequency distribution of the number of times bumblebees visited *Spiranthes romanzoffiana* plants ranked by near neighbor distances (1st = closest plant; Chi-square analysis with null hypothesis being that of a uniform distribution, n = 176; $P < 0.05$).

via those directions were comparable (44%, 34%, and 12%, respectively).

Foraging sequences. During a foray, bees varied their sequence of visits from one plant to the next, mostly zigzagging along a westerly-southeasterly route. The bees alternated right and left-hand turns 53% of the time (non-alternating 34% of the time), went straight (5%), and reversed directions (8%) (n = 78).

Departure angles. Examination of the frequency distribution of departure angles revealed nearly symmetrical bimodal peaks between 45-90° (Figure 4). This showed that almost 50% of the time the bees were selectively aiming toward plants within those 45° sectors, equally turning right and left; similarly, the bees also aimed within 90-135° sectors (about 1/4 of the time), and between 135-180° (1/8) and 0-45° (1/8). The distribution deviates from uniform ($P < 0.001$, n = 130) because of the lack of a unimodal peak at 0° and because of the few departures at the most obtuse and most acute angles.

Flight distances. While within the study area, the bees flew an average distance of 10 m per foray, the maximum distance being over 28 m; 50% of the forays were < 6 m in length. The shortest distance the bees flew between plants was 0.4 m (between plant # 5 and # 6); the longest, 9.3 m (between plant #2 and #11). The bees performed 33 visit combinations (i.e., flight between any two plants) among the 12 plants (66 visit combinations possible), with a mean distance of 3.8 m travelled between plants.

Factors affecting visitation. The frequency distribution of the relative number of times the bees flew to plants ranked according to their nearest neighbor is shown in Figure 5. Only 40% of the visits were made to the closest plants.

Quantitative comparison of the various factors which affected the bees' behavior showed that the number of bee visits were significantly correlated with the following (in descending order of importance): (1) inflorescence length and plant height (these two variables were so highly intercorrelated that it was not possible to determine which one, or if both, was the major cue); (2) distance to nearest neighbor; and (3) number of open flowers (Table 1; Figure 6).

Further analyses (Table 2) using variable Set 1 (*see* Materials and Methods) and least-squares-regression analyses showed that the order of significance (based on partial correlations, pr^2) was: (1) inflorescence length ($pr^2 = 0.77$,

TABLE 1. Results of Spearman Rank Correlation Analysis for factors affecting total number of bumblebee visits to *Spiranthes romanzoffiana*.

	Correlation Matrix*			
	Spike Height	Inflorescence Length	No. of Open Flowers	Distance to Nearest Neighbor
Total No. Visits (n = 224)	0.92	0.92	0.72	-0.77
Spike Height (n = 12)		0.93	0.72	-0.61
Inflorescence Length (n = 12)			0.88	-0.70
No. of Open Flowers (n = 12)				-0.67

*Critical Value ($P < 0.05$) 2-tailed = ± 0.57.

TABLE 2. Results of Regression Analyses to determine which predictor variables had the greatest effect on the number of bee visits.

Predictor Variable	Partial r^2	P
Variable Set 1* (n = 12)		
Inflorescence length	0.77	< 0.001
Number of open flowers	0.37	0.06
Nearest neighbor distance	0.36	0.07
Variable Set 2† (n = 12)		
Plant height	0.74	0.001
Nearest neighbor distance	0.41	0.05
Number of open flowers	0.01	0.83

*r^2 for regression using Set 1 = 0.93, $P < 0.001$, DF = 8.
†r^2 for regression using Set 2 = 0.91, $P < 0.001$, DF = 8.

$P < 0.001$); (2) number of open flowers ($pr^2 = 0.37$, $P = 0.06$); and (3) nearest neighbor distance ($pr^2 = 0.36$, $P = 0.07$) (r^2 for the regression = 0.93, $P < 0.001$, DF = 8). For Set 2, the rank order was: (1) total plant height ($pr^2 = 0.74$, $P = 0.001$); (2) nearest neighbor distance ($pr^2 = 0.41$, $P = 0.05$); and (3) number of open flowers ($pr^2 = 0.01$, $P = 0.83$) (r^2 for the regression= 0.91, $P < 0.001$, DF = 8). Similar results were obtained from stepwise regression analyses. These results strongly suggested that conspicuousness (i.e., spike height and/or inflorescence length) was the primary factor determining which plants were visited by *Bombus bifarius*.

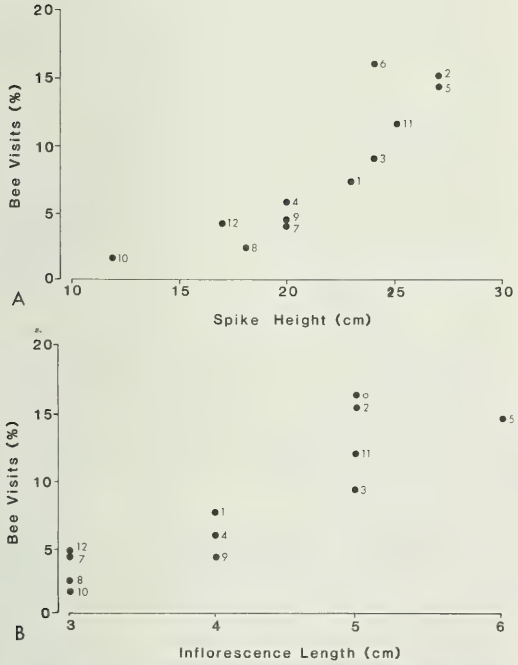

FIGURE 6. Scatterplots of "conspicuousness" parameters of *Spiranthes romanzoffiana* versus percent of total visits by bumblebees (n = 224; number at circle = study-area plant).

Discussion

Although results herein are based on only two days of observations, they represent the most detailed descriptions of bumblebee foraging behavior at any terrestrial orchid. Observations of bumblebees on other plants with inflorescences (e.g., fireweed) have shown that arrival rates of bees varied considerably from day to day according to weather conditions (Schmid-Hempel and Speiser 1988). Previous studies of bumblebee-pollinated orchids emphasized pollination mechanisms (e.g., Ackerman 1975, 1981; Catling 1983). In general, it is more difficult to study the foraging behavior of orchid-pollinating insects, in part because the pollination event is so brief and because pollinators are so few (e.g., Ackerman 1975, 1981; Catling 1983).

Comparison of previous studies of foraging bumblebees with our results is complicated because of the number of variables involved (e.g., flower morphology, spatial arrangements of flowers and plants, and different bee species and individual behavioral repertoires). However, reports of bumblebees foraging on wildflowers generally agree on several accounts: (1) the bees tend to concentrate in rich (rewarding) areas, moving preferentially between near neighbors (equally right and left); (2) they move quickly through depleted areas; and (3) they minimize flower revisits (Heinrich 1976, 1979b; Pyke 1978; Hodges and Miller 1981; Zimmerman 1982; Schmid-Hempel and Speiser 1988). In one study, however, bumblebees (*Bombus appositus*) preferred a less rewarding, dispersed plant site over a higher density site with more nectar-rich flowers (Hodges and Wolf 1981).

Foraging patterns of bees vary depending on a number of factors such as flower attractiveness, plant distribution, the probability of flower revisitation, and ultimately, on the bees' acquired skills (e.g., whether the bee is "naive" or "specialized" [Tinbergen 1958; Heinrich 1976]; degree of short or longterm memory and knowledge of rewards: Pyke 1978.

General flight path. In our study, directionality was initially influenced by where the bees entered the orchid patch. Apparently, the bees were then visually directed by plant position and "conspicuousness" (i.e., inflorescence length and spike height). Thus, the bees zigzagged in either direction along a predictable path within the patch, with variously sequenced visits to plants along the way, suggesting that the bees were probably traplining

(Heinrich 1979a) through the forest. The bees did not "beeline" across the study area, nor did they fly randomly. Heinrich (1976) noted that when a foraging area contained recognizable landmarks and was relatively small, that bumblebees directionally foraged when traplining.

Interplant flights. Herein, the bees directed their successive interplant flights (relative to arrival direction) by flying mostly toward plants within 45-135° sectors (equally right and left). This behavior may have resulted, in part, because bee "visual acuity is best in a narrow vertical field anterolaterally directed" (Michener 1974). Previous studies have shown a unique frequency distribution of departure angles, although they are all symmetrical around zero degrees (i.e., number of right and left turns are equal) (Pyke 1978; Hodges and Miller 1981; Zimmerman 1982). The disparities among the frequency distributions are apparently the result of the distribution and type of resource rather than species-specific foraging behavior.

Repeat visits. Previous researchers have stressed that bees usually avoid recently-visited flowers (e.g., those without nectar or pollen rewards) (Heinrich 1979a, 1979b; Zimmerman 1982). Bees accomplish this in several ways, e.g., by differentiating recently visited from unvisited flowers by visual or scent cues (Zimmerman 1982; Corbet et al. 1984; Schmitt and Bertsch 1990), by foraging upwards on vertical inflorescences (Heinrich 1979b), and/or by minimizing revisits by foraging from a fraction of the flowers on a plant (Hodges and Miller 1981; Schmid-Hempel and Speiser 1988).

In our study, we were unable to determine whether the bees repeatedly visited the same flowers, although they certainly revisited the plants. However, during a given foray, the bees rarely made immediate repeat visits to plants. The bees performed nonrepeated foraging sequences 80% of the time, yet intensely revisited four of the most "conspicuous" plants. Repeated foraging sequences (20%) similarly involved many revisits to the most "conspicuous" plants (up to three visits to the same plant), although such revisits were usually not in succession. Nonetheless, because of the high frequency of visits (every four minutes) to the four "key" plants, it is likely that some of the flowers were recently revisited, suggesting nonoptimal foraging behavior.

High visitation rates usually indicate high nectar rewards (e.g., Heinrich 1976, 1979a; Schmid-Hempel and Speiser 1988). Flowers mainly visited by bumblebees have been shown to secrete about 1 mg of sugar per day (von Frisch 1965 and Heinrich 1976, *cited in* Bertsch 1983). Relative to other nectar-producing, but infrequently visited, terrestrial orchids, e.g., *Calopogon pulchellus* (Heinrich 1976) and *Goodyera oblongifolia* (Ackerman 1975), the high revisitation rate by bumblebees foraging on *Spiranthes* inflorescences is unusual, suggesting large rewards.

High visitation rates could be advantageous to individual bees because they could monopolize a resource by reducing it to the point whereby it would be unprofitable for other bees to utilize it by switching from another resource or by learning to forage from it (Laverty 1980; Corbet et al. 1984).

Near neighbor factor. Bees may preferentially visit nearby plants (Pyke 1978; Zimmerman 1982) because reduction of flight time may enhance foraging efficiency (Heinrich 1979a). Yet, in a study by Hodges and Miller (1981), foraging bumblebees only visited nearest plants about 25% of the time; the authors suggested that the longer flights would reduce revisitation. We determined that near-neighbor visits occurred 40% of the time, suggesting that other factors were more important in determining visitation rates. Apparently, the bees were attracted by the more noticeable, relatively distant plants.

Importance of plant conspicuousness in low density flower patches. The data presented herein suggest that perceived rewards, due to the "conspicuousness" of the plant (i.e., inflorescence length and/or plant height), were most important in controlling foraging. Schmid-Hempel and Speiser (1988) similarly found more bee visits to "larger" inflorescences.

Previous studies that dealt with high-density flower patches, where interplant distances were relatively short, showed that plant "conspicuousness" was less important. In these situations, bees forage randomly, thus not utilizing landmarks or directional pathways (Tinbergen 1958; Heinrich 1979b; Hodges and Miller 1981; Zimmerman 1982).

However, in this study, where plants were variously sized and usually several meters apart, the bees apparently responded to individual "conspicuous" plants, in the direction of travel. This is adaptive in a trapline situation because bees only have to remember a few landmarks and direction of travel.

Summary. This study corroborates those of others in revealing the extensive behavioral plasticity of foraging bumblebees (i.e., behavior is unique in each situation). Thus, the relative importance of individual parameters changes as the foraging bees respond to an amalgam of environmental stimuli. Results herein showed that plant conspicuousness was the overriding factor that "lured" the bees to forage nonrandomly with respect to direction and

to bypass nearest neighbors. This factor was so important that it also caused the bees to revisit the same plants at higher rates than might have been optimal, indicating a need to reexamine bee/flower interactions as an active partnership.

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Annual Smartweeds in the Prairie Provinces

RICHARD J. STANIFORTH and LYNN M. BERGERON

Department of Biology, University of Winnipeg, 515 Portage Avenue, Winnipeg, Manitoba R3B 2E9

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Several annual smartweeds are amongst the most serious weeds in prairie fields. Field biologists often lump similar species, and thus overlook their ecological differences. In this study, herbarium specimens were examined to determine relative abundances of taxa, distributions, patterns of spread, habitats and to draw up a species comparison table. Six species occurred in the Canadian prairies: Water Pepper (*Polygonum hydropiper*), Pale Smartweed (*P. lapathifolium*; varieties *lapathifolium, prostratum, salicifolium*), Pennsylvania Smartweed (*P. pensylvanicum* var. *laevigatum*), Lady's Thumb (*P. persicaria*), Dotted Smartweed (*P. punctatum* var. *confertiflorum*) and Green Smartweed (*P. scabrum*). *Polygonum lapathifolium* is by far the most abundant species (72% of all specimens examined), but both *P. scabrum* and *P. persicaria* are locally common (13% and 7% of specimens respectively), *Polygonum hydropiper* and *P. punctatum* are scarce (1% and 3%, respectively), and restricted to the eastern prairies. A single specimen of *P. pensylvanicum* forms a first record from the region. The asiatic Prickly Smartweed (*P. bungeanum*) has recently become a localised but aggressive introduced weed in Minnesota and should be watched for in Canada. *Polygonum lapathifolium, P. scabrum* and *P. persicaria* are found throughout the prairie provinces, whereas *P. hydropiper* and *P. punctatum* are restricted to southern Manitoba, or southern Manitoba and central Saskatchewan, respectively. *Polygonum scabrum* and *P. hydropiper* are recent introductions (since 1930) from Eurasia and are spreading quickly from the west, or slowly from the east, respectively. *Polygonum persicaria* is a long established Eurasian weed present in Manitoba for almost 100 years, and is spreading slowly throughout the prairies, probably in a westward direction. *Polygonum lapthifolium* and *P. punctatum* are either partly or entirely native species whose abundances and perhaps distributions have probably increased as a result of an increase in habitat disturbance by human activities. *Polygonum scabrum* and *P. lapathifolium* are often serious weeds in cereal fields. *Polygonum persicaria* is also weedy but more frequently encountered in domestic or market gardens or waste areas. These three species are likely to become more serious weeds as their abundances and distributions increase or as new more vigorous genotypes evolve or are accidentally introduced. *Polygonum hydropiper* and *P. punctatum* are most frequent in wet places like ditches and shore-lines and do not seem to be potentially serious weeds. Each of the six species may be distinguished in the field by its own peculiar set of ocrea, flower and achene characteristics.

Key Words: Smartweeds, *Polygonum hydropiper, Polygonum lapathifolium, Polygonum pensylvanicum, Polygonum persicaria, Polygonum punctatum, Polygonum scabrum,* distribution, prairies.

Annual species of smartweeds (genus *Polygonum*, section *Persicaria*) are colonizers of damp, disturbed substrates, such as ditches, beaches and riverbanks (Scoggan 1978). As a group smartweeds are also amongst the most abundant weeds in the prairie provinces (Thomas and Wise 1987, 1988). Morphological similarity and, to a lesser extent, nomenclatural disagreement, have meant that field workers find it advantageous to lump the taxa as "smartweeds". This is unfortunate because specific and varietal differences in ranges, abundances, and habitats are often masked by such lumping (Staniforth and Cavers 1979). The present study was intended to clarify which annual smartweed taxa occur in the Canadian prairie provinces (Manitoba, Saskatchewan, Alberta), to determine their relative abundances, to plot and compare distributions, patterns of spread and habitats, and to make a comparison table to allow rapid identification.

Methods

Smartweed specimens were examined from the following herbaria: CAN, DAO, UWPG, WIN, MMMN, WRNE, SASK, DAS, SCS, ALTA, UAC, LEA (see Holmgren et al. 1981), the Krivda herbarium and that of the University of Regina. Specimens were identified to species and variety using morphological characteristics. Specimens were then annotated and their geographical locations plotted (Figure 1). The assumption was made that collection bias would not distort our perception of abundance, habitat or distribution of taxa. Similarities in size, conspicuousness and accessibility of habitat between species supported this premise.

Results and Discussion

Relative abundances of species

We followed the nomenclature of Scoggan (1978). It is reasonably current, widely used, and his treatment of *Polygonum*, section *persicaria* is generally accepted in Canada. Taxonomic revision was not the aim of this paper and so we do not vary from his nomenclature. Six species (*P. hydropiper, P. lapathifolium, P. pensylvanicum, P. persicaria, P. punctatum, P. scabrum*) and several varieties

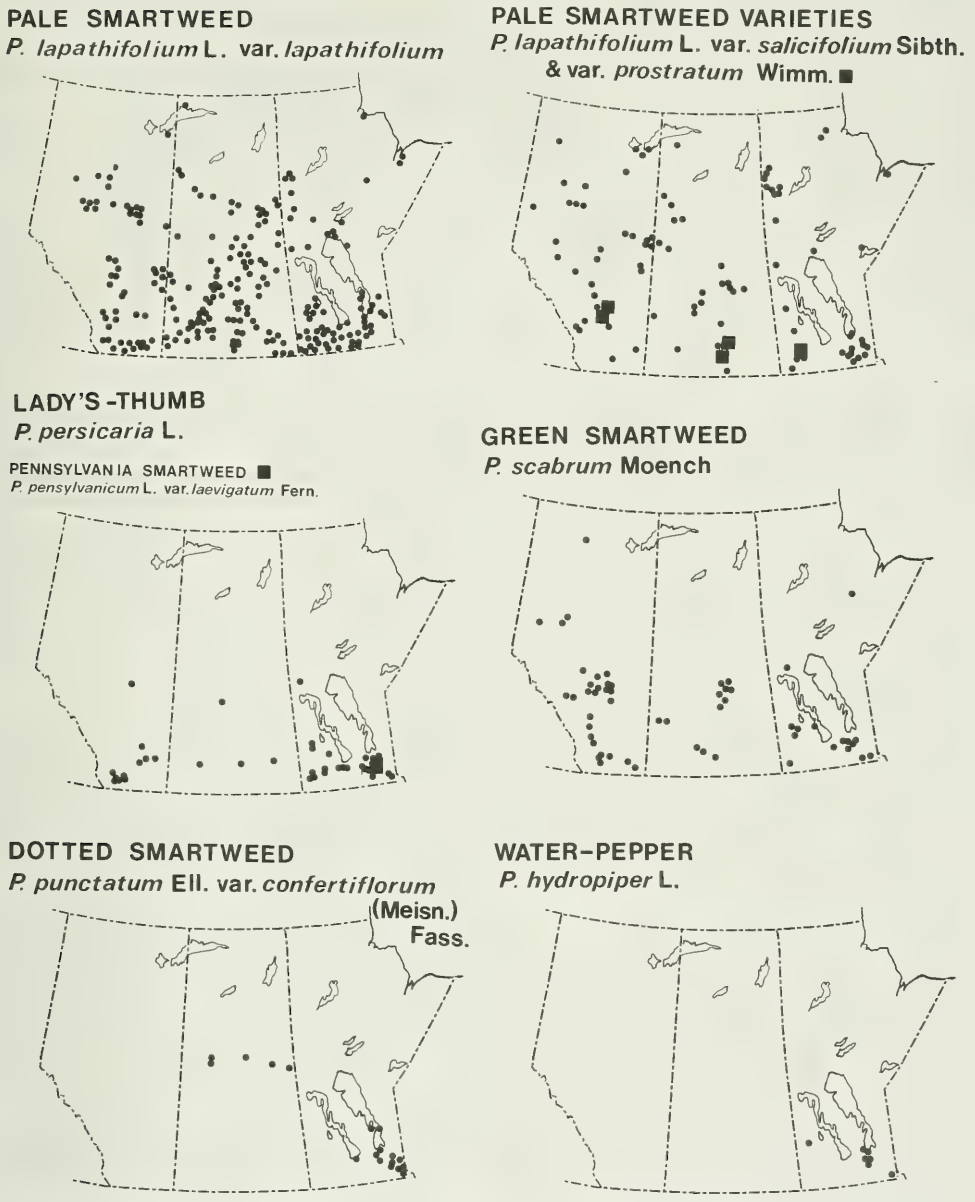

FIGURE 1. Distribution of annual smartweeds (*Polygonum* spp.) in the Canadian prairie provinces.

were amongst the 715 specimens examined (Table 1). Unique combinations of morphological characters made species identification straightforward for most specimens (Figures 2 and 3, Table 2). By far the majority of plants (72%) were *P. lapathifolium; P. scabrum* (13%) and *P. persicaria* (7%) were considerably scarcer, and the remaining species were very rare (< 4%). *Polygonum pensylvanicum* was represented by one collection. About 25% of specimens of *P. scabrum* and *P. lapathifolium* showed characters normally considered diagnostic of one species or the other. Usually this involved only one or two characters, but in 4.5% of the cases the specimens were truly intermediate and assignment of these specimens to either species would have been arbitrary.

It is unknown whether intermediates are a result of interspecific hybridization and introgression or whether *P. scabrum* is an extreme form within the very variable *P. lapathifolium* complex, as has

TABLE 1. Taxa of annual smartweed species occurring in the Canadian prairies and numbers of specimens from each region. Based on specimens in national and prairie herbaria examined 1986-1987.

Names	Numbers of Specimens Alberta	Saskatchewan	Manitoba	Totals
Water Pepper, *Polygonum hydropiper*	0	0	10	10
Pale Smartweed, *P. lapathifolium* (all vars.)	172	156	184	512
Pennsylvania Smartweed, *P. pensylvanicum*	0	0	1	1
Lady's Thumb, *P. persicaria*	11	4	32	47
Dotted Smartweed, *P. punctatum*	0	6	18	24
Green Smartweed, *P. scabrum*	65	12	16	93
Green-pale Smartweed, intermediates	9	11	8	28

been proposed by Barkley (1986) and Webb and Chater (1964). *Polygonum scabrum* and *P. lapathifolium* have the same chromosome number of 2n = 22 (Mulligan 1961; Mulligan and Porsild 1969; Löve and Löve 1975).

Varieties

Determination to variety level was made with less confidence than to specific rank, because smartweeds show considerable phenotypic plasticity. It was a trend in the past to name as much variation as possible, e.g. division of the European *P. lapathifolium* complex into approximately 70 named infra-specific taxa (Danser 1921), whereas, only a few particularly conspicuous or abundant phenotypes are currently recognized. In this study, difficulties arose when variety status had been based on a single character, when characters of two varieties were combined in a single individual, or with different interpretations of diagnostic characters by determiners.

Polygonum hydropiper is represented in Canada by the typical variety and a long-pedicelled extreme, named var. *projectum* Stanford (Scoggan 1978). All specimens appeared similar and were annotated as var. *hydropiper*. Pedicel length is an unreliable character in herbarium specimens because it may depend on the stage of flower maturity.

Canadian material of *P. lapathifolium* has been determined as belonging to four varieties: *lapathifolium, ovatum* A. Br., *prostratum* Wimm. and *salicifolium* Sibth. Varieties *lapathifolium* and *salicifolium* are abundant and usually distinct from each other in shape, size and pubescence of leaves, and posture and length of inflorescences (Figure 2). Many of the 500 specimens of these varieties had mixed characters but only four were not assignable because of equivalent numbers of characters from each variety. Fassett (1968) suggested that plants of var. *salicifolium* may be merely immature specimens of var. *lapathifolium*. Our field observations suggest that immature plants of both varieties have certain characters in common (e.g. leaf pubescence), but the differences become distinct as the plants age. Twelve specimens of *P. lapathifolium* resembled the wide-leaved varieties *ovatum* or *prostratum*; but of these only five (all of var. *prostratum*) did not have more attributes of a commoner variety. The specimens of *P. pensylvanicum* were assigned to var. *laevigatum* Fern. and to form *pallescens* Stanford on the basis of yellowish peduncle glands, more or less glabrous lower leaf surfaces and pink flowers.

The 47 specimens of *P. persicaria* appeared to be of the typical variety, despite a few previous determinations of *P. ruderale* Salisb. or *P. persicaria* var. *ruderale* (Salisb.) Meisn.

Specimens of *P. punctatum* had been assigned to three varieties: *punctatum*, a perennial; *leptostachyum* (Meisn.) Small, an annual; and *confertiflorum* (Meisn.) Fassett, also an annual. According to Boivin (1968) var. *leptostachyum* is a Javanese variety and Canadian material is unlikely to be of this taxon. The specimens of var. *punctatum* were so determined because they possessed adventitious roots at lower nodes and that this had suggested perennation. We believe that this indirect clue to be misle ading and that it has led to misidentifications because adventitious roots are often produced as a result of a flooded habitat. It appears that all 24 specimens of *P. punctatum* are of var. *confertiflorum*.

Polygonum scabrum has no infra-specific taxa.

Origins, patterns of spread and current distributions

Scoggan (1978) indicated that the North American material of *P. hydropiper* is at least partly or entirely of Eurasian origin. It has been only recently collected from the prairies (at Winnipeg in 1940). An earlier specimen collected by John Macoun from Washow Bay, Lake Winnipeg in 1884 (cited by Scoggan 1957) was actually *P. punctatum*. It seems that *P. hydropiper* is a recent adventive to the prairies and is slowly extending its range in a north-westward direction across Manitoba in wet, disturbed sites (e.g. roadside ditches). Currently, the species is locally distributed along the southern edge of the boreal

FIGURE 2. Prairie smartweeds showing differences in arrangement, shape, size and posture of flowering spikes: (1) Pale Smartweed, *P. lapathifolium*; (1a) var. *lapathifolium*, (1b) var. *salicifolium*; (2) Lady's Thumb (*P. persicaria*); (3) Pennsylvania Smartweed, *P. pensylvanicum*; (4) Dotted Smartweed, *P. punctatum*; (5) Water Pepper, *P. hydropiper*; (6) Green Smartweed, *P. scabrum*.

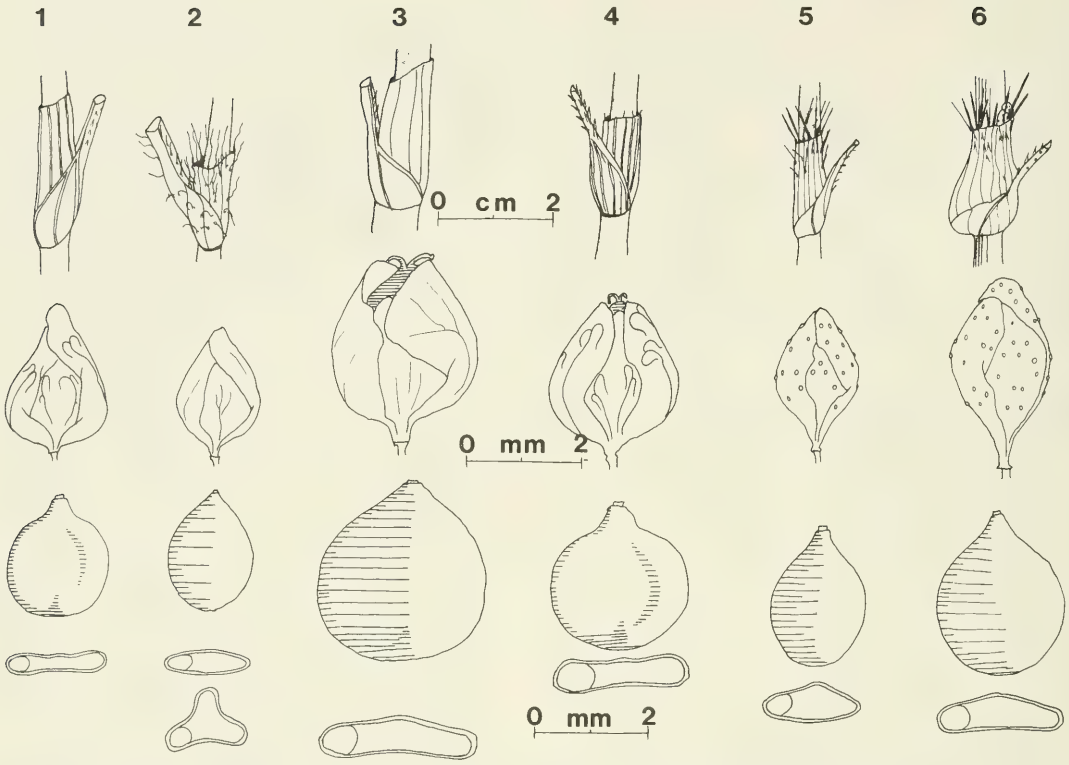

FIGURE 3. Diagnostic field characteristics of prairie smartweeds. (1) Pale Smartweed, *P. lapathifolium*; (2) Lady's Thumb, *P. persicaria*; (3) Pennsylvania Smartweed, *P. pensylvanicum*; (4) Green Smartweed, *P. scabrum*; (5) Dotted Smartweed, *P. punctatum*; (6) Water Pepper, *P. hydropiper*. Top row: ocreae. Second row: achenes with perianths. Third row: achenes. Bottom row: achenes in cross-section.

forest and does not seem to have colonized farmlands.

Polygonum lapathifolium is an abundant native plant of damp and disturbed sites, including farmland where it can be a serious weed. It was collected by early botanists in the prairies, e.g. John Macoun on his expeditions between 1872 and 1896 (Table 3). It is likely that weedy genotypes from Eurasia have augmented North American material. For instance, recent collections have been made of the Eurasian varieties: *prostratum* and *ovatum*. Variety *lapathifolium* is abundant throughout the southern and central sections of the prairie provinces but is replaced northwards by var. *salicifolium*. This pattern has also been recognized in Ontario (Staniforth and Cavers 1979). Variety *salicifolium* does not appear to be a serious weed, but this may be because it is found north of the major cereal growing regions. Specimens of var. *salicifolium* from mid- and southern prairies usually showed some characteristics of the typical variety and are likely to be infravarietal hybrids.

Polygonum pensylvanicum is found throughout the eastern United States, north to Minnesota and South Dakota (Fernald 1950), southern Ontario (Staniforth and Cavers 1979) and the maritime provinces (Scoggan 1978). The Canadian prairies appear to be beyond the normal range of this species. Three plants were found at Fort Whyte Centre for Environmental Studies, Winnipeg in 1981, one of which was collected (UWPG 3055). They were growing in a dried pond amongst plants of *P. lapathifolium*. It is possible that the achenes of these plants had been brought into the area from further south by waterfowl visiting the ponds as waterfowl are known to feed on smartweed achenes (Ridley 1930). Examination of the site in subsequent years did not reveal any more plants of this species. It can be expected that short-term, isolated colonies may appear from time to time in southern Manitoba, especially where there are concentrations of waterfowl, or where unclean crop seeds are introduced from eastern or southern North America. Previous reports of *P. pensylvanicum* in the prairies (e.g. Scoggan 1957) have been assigned to *P. lapathifolium*, by Boivin (1968).

Polygonum persicaria is a Eurasian species which was present in Manitoba in the nineteenth century. Dates are progressively later for the

TABLE 2. Diagnostic characteristics which can be used in the field for identification of annual smartweeds in the Canadian prairies.

Characteristic	Smartweed Species					
	Polgonum lapathifolium	*Polgonum persicaria*	*Polgonum pensylvanicum*	*Polgonum scabrum*	*Polgonum hydropiper*	*Polgonum punctatum*
Ocrea bristles	absent	present	absent	minute or absent	usually present	usually present
Flower colour	pale green, white or pink (rarely red)	pink (rarely white or green)	pink (rarely white)	green (rarely purplish)	green, white or red-streaked	white to green (rarely pink)
Achene						
colour	brown	black	dark brown	brown	black	black
texture	shiny	shiny	shiny	shiny	dull	highly glossed
length (mm)	1.5-2.5	2.0-3.0	2.5-4.0	2.5-4.0	2.0-4.0	2.5-3.0
shape	lenticular, biconcave	lenticular, biconvex (or trigonous)	lenticular, flat to biconcave	lenticular, biconcave	lenticular, biconvex (or trigonous)	lenticular, biconvex

western provinces, suggesting a spread in a western direction. Most specimens are from urban centres or adjacent farmland. At present, the species is only locally abundant and does not appear to be a noxious weed in farmland; however, it is often frequent in domestic and market gardens, nurseries and greenhouses. A few specimens were examined which had been collected from more natural sites, such as pond edges. This species is expected to become more abundant, widespread and, perhaps a more serious weed over a period of time, as it has in eastern Northern America and Europe.

Polygonum punctatum is a native species which appears to be rare in Manitoba and Saskatchewan, and absent in Alberta. It is found on damp beaches and pond edges, and does not appear to be a threat to agriculture. The range largely matches that of *P. hydropiper* but extends further to the northwest. Records from Manitoba date to the last century, while those in the west, like those of *P. hydropiper*, are more recent.

Polygonum scabrum, like *P. persicaria* is an introduced Eurasian weed, but unlike that species, *P. scabrum* is relatively recent, spreading from west to east, has become abundant relatively quickly, and is more of a problem in grain crops. The earliest record of its occurrence is a specimen from Alberta collected in 1931. Eastern prairie specimens are more recent. It is interesting that the first collection from Manitoba is from Gillam which is far north and east of its contemporary distribution and also outside of its normal agricultural habitat. It is likely that this specimen came in with rail grain shipments from the western prairies to the sea port at Churchill. Subsequent populations in Manitoba appeared in southern croplands. Most specimens had been collected from fields of wheat, barley or oats with which this species is often a serious weed. *Polygonum scabrum* is likely to become a more serious weed as its range and abundance continue to increase.

Other annual smartweeds possessing weedy attributes and which occur in adjacent provinces or states may be expected to turn up in the Canadian prairies in the future. Amongst these are: Prickly Smartweed (*P. bungeanum*), a recent and aggressive adventive from Asia into Minnesota, where it has become a serious local weed (Andersen, Lueschen and Zaremba 1985); Prince's Feather (*P. orientale*), sometimes grown as a garden ornamental; and Carey's, Long-styled and Tufted smartweeds (*P. careyi* Olney, *P. bicorne* Raf., *P. cespitosum* BP), which are all native species of damp thickets and cultivated land of eastern North America, including Ontario and Minnesota. *Polygonum bungeanum* alone is potentially weedy.

Diagnostic Field Characters

A comparison table was constructed to allow field workers to identify annual smartweeds to the species level without the need of microscope, hand lens or special equipment. Each species has a unique combination of morphological characters, many of which are illustrated in Figures 2 and 3, and summarized in Table 2.

Field procedure is to ensure that the specimen is an annual smartweed. This is done by ascertaining the following characteristics: absence of rhizome or perennial rootstock, presence of a membranous leaf sheath (ocrea), the leaves are simple and lance-shaped; flowers green, white, pink or red and arranged in terminal spikes; and presence of single dark brown or black seed (achene) per flower. Within this group identification is more subtle, but straightforward. The first field character is the

TABLE 3. Dates, locations and accession numbers of earliest collections of prairie smartweeds.

Taxon	Alberta	Saskatchewan	Manitoba
Pale Smartweed			
P. lapathifolium			
var. *lapathifolium*	1906 Battle River CAN 44241	1879 Red Deer Lakes CAN 44238	1896 Brandon CAN 44234
var. *salicifolium*	1884 Medicine Hat CAN 44272	1936 Wallwort SASK 10024	1884 Muskeg Island CAN 44266
var. *prostratum*	1971 Drumheller ALTA 42449	1963 Regina DAS 077122	1977 Brandon Krivda herb.
Water Pepper			
P. hydropiper	absent	absent	1940 Winnipeg DAO 515942
Pennsylvania Smartweed			
P. pensyvanicum	absent	absent	1981 Winnipeg UWPG 3055
Lady's Thumb			
P. persicaria	1931 Edmonton ALTA 7676	1910 Middle Lake DAO 408958	1896 Brandon CAN 44564
Dotted Smartweed			
P. punctatum	absent	1949 Ile à la Crosse SASK 9708	1884 Washow Bay CAN 44480
Green Smartweed			
P. scabrum	1931 Fort Sask. SASK 10027	1937 Mortlach SASK 10044	1950 Gillam CAN 408891

presence/absence of bristles on the ocreae. It is necessary to select an ocrea on a younger part of the plant because ocreae tend to tear with age. All other field characters relate to flowers and achenes. Flower (perianth) colour is variable within some species. It is more or less constant through all stages of flower maturation, from the bud stage to the maturation of the achenes. Achenes may be obtained by collecting the flowers and fruit in the palm of the hand then freeing achenes from the perianths by rubbing with the thumb. Immature achenes are straw-coloured and quite different from those that are mature. Therefore, differences in surface textures, shapes, sizes or colours (apart from straw-coloured) are reliable differences between species and not related to maturity. Surface textures of achenes reflect light in different ways with the result that achenes may appear dull, shiny or highly glossed. There is some variability within species regarding size and shape of achenes but these characters can provide useful diagnostic information as long as a sample of 20-30 achenes is examined. Achenes may be disc-shaped (lenticular) or triangular in cross section (trigonous), in addition they may be dimpled on one or both surfaces (biconcave), flat or lens-shaped (biconvex). Colour of mature achenes is medium brown, dark brown or black depending on species. Length of achenes can be used to separate the large-seeded species (*P. scabrum, P. pensylvanicum*) from the remainder. This requires the ability to distinguish between seeds which are closer to 3 mm in length as opposed to 2 mm in length. This is not hard to do, after some practice. Other characters are diagnostic but are difficult to see without a hand lens, e.g. the presence of anchor-shaped veins in the perianth segments (*P. lapathifolium, P. scabrum*), gland-dotted perianths (*P. hydropiper, P. punctatum*), glandular peduncles (all except *P. lapathifolium, P. persicaria*) and occurrence of flowers and achenes within specialized ocreae (*P. hydropiper*). Chromosome numbers differ between some taxa, e.g. *P. lapathifolium* 2n = 22, *P. persicaria* 2n = 44 (Löve and Löve 1975).

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Seasonal Distribution and Site Tenacity of Black-crowned Night-Herons, *Nycticorax nycticorax*, Banded in Canada

LOUIS P. L'ARRIVÉE[1] and HANS BLOKPOEL

Canadian Wildlife Service, Ontario Region, 49 Camelot Drive, Nepean, Ontario K1A 0H3
[1]Present Address: Toxicology Evacuation Division, Health and Welfare Canada, Health Protection Building, Tunney's Pasture, Ottawa, Ontario K1A 0L2

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We analyzed 99 recoveries of Black-crowned Night-Herons (*Nycticorax nycticorax*) banded in Canada during 1942-1986 (97 banded as chicks, one banded as an after-hatching year bird, one banded at an unknown age). Birds banded in Ontario and Quebec migrated south during September and October, wintered on the islands of Cuba, Jamaica, Hispaniola, and the Bahamas during November through March, and most were found in their natal province during April through August. Birds banded in the Prairie Provinces (Manitoba, Saskatchewan, and Alberta) were recovered as far south as Oklahoma during September-October, and occurred in South Carolina, Cuba, and Mexico during November through March, while only one recovery of an adult in North Dakota occurred during the April through August period. For Black-crowned Night-Herons banded in Canada, the majority of adults and yearlings were recovered within 250 km of their original banding locations during April through August, a few even within the same 10′ latitude × 10′ longitude block. This suggests strong tenacity to natal area and possibly to the natal colony sites.

Nous avons fait l'analyse de 99 récupérations de Bihoreaux à couronne noire (*Nycticorax nycticorax*) qui avaient été bagués au Canada de 1942 à 1986 (97 bagués à l'âge d'oisillon, un bagué à l'âge d'un an et un d'âge inconnu). Les oiseaux bagués en Ontario et au Québec ont émigré vers le sud en septembre et octobre pour se retrouver de novembre à mars sur les îles du Cuba, de la Jamaïque, de Hispaniola, et des Bahamas. La plupart a été retrouvée à leur endroit natal d'avril à août. Les oiseaux bagués au Manitoba, en Saskatchewan, et en Alberta ont été retrouvés en septembre et octobre aussi loin dans le sud qu'en Oklahoma. Ils étaient présents de novembre à mars dans la Caroline du Sud, le Cuba, et le Mexique. Un adulte seulement a été récupéré d'avril à août dans le Dakota du Nord. La majorité des Bihoreaux à couronne noire adultes et jeunes âgés d'un an, bagués au Canada, a été retrouvé d'avril à août à l'intérieur d'un rayon de 250 km du site original où ils ont été bagués. Quelques-uns ont même été retrouvés dans leur carré natal de 10′ latitude × 10′ longitude. Ceci suggère une tenacité forte à leur endroit natal et peut-être même au site de leurs colonies natales.

Key Words: Black-crowned Night-Heron, *Nycticorax nycticorax*, seasonal distribution, site tenacity, Canada, breeding range, winter range.

The Black-crowned Night-Heron (*Nycticorax nycticorax*) is widespread with breeding ranges in North and South America, Africa, and Eurasia (Palmer 1962; Hancock and Kushlan 1984). There are two large breeding ranges in North America (*see* Figure 1).

This species appears to have expanded its breeding range in Canada over the past 30 years. Palmer's (1962) map for the Black-crowned Night-Heron did not include Alberta and Nova Scotia. In Alberta it was first observed in 1958 and, since then, it has remained in the province as a local breeder (Salt and Salt 1976). In Nova Scotia, there were only 25 records prior to 1960, but subsequently it has been reported every year in increasing numbers with the first record of breeding in 1977 (Tufts 1986). Goodwin (1987) reported that this species expanded its range in Ontario during the 1950s, and although the population declined in the 1960s and 1970s, he suggests that it is once again expanding its range as evidenced by the discovery of new nesting areas during 1981-1985.

Figure 1 shows that British Columbia is not included in either of the two large North American breeding ranges. The Black-crowned Night-Heron was listed as extra-limital in British Columbia by Munro and Cowan (1947). However, sightings of this species in the Okanagan Valley have become increasingly regular since 1974 (Cannings et al. 1987) and one 1978 breeding record exists for the Fraser River delta (Butler and Campbell 1987). Butler and Campbell (1987) also state that young-of-the-year are seen in July in the Fraser River delta.

The winter range of the Black-crowned Night-Heron in North America is south from southern Oregon, southern Nevada, northern Utah, central New Mexico, southern Texas, the lower Ohio Valley, Gulf Coast, southern New England through to Central America and the Caribbean islands (Palmer 1962; A.O.U. 1983). Apparently,

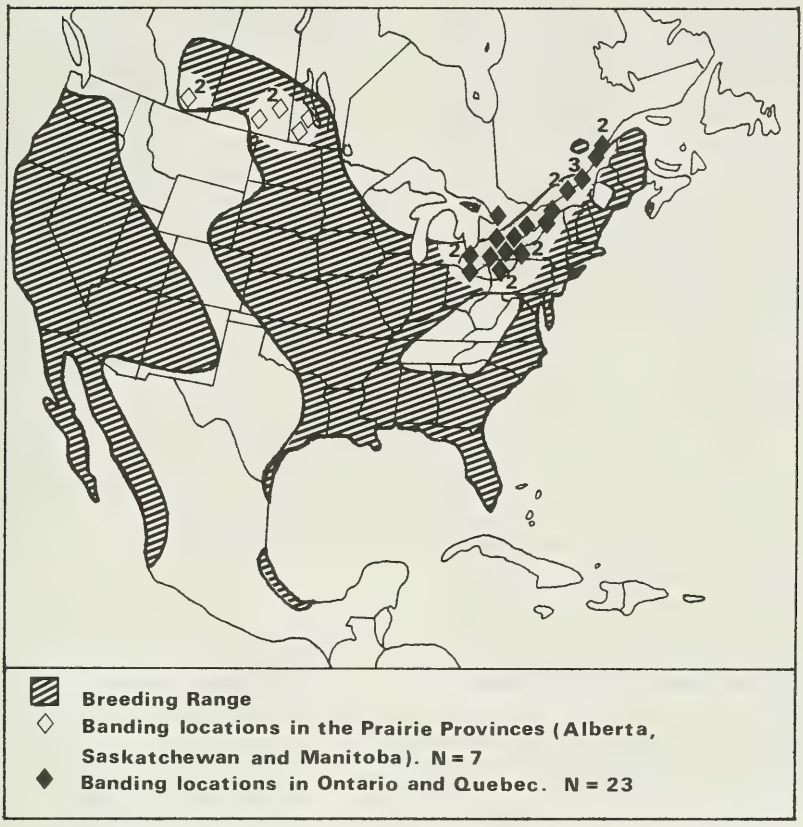
Breeding Range
Banding locations in the Prairie Provinces (Alberta, Saskatchewan and Manitoba). N = 7
Banding locations in Ontario and Quebec. N = 23

FIGURE 1. North American breeding ranges of the Black-crowned Night-Heron (adapted from Hancock and Kushlan (1984) for the USA and Mexico and from Godfrey (1986) for Canada) and banding locations of Black-crowned Night-Herons in Canada for which recoveries have been reported during 1942-1986. Symbols with numbers indicate two or more banding locations within 40 km of each other.

birds originating from the western breeding range winter in Mexico and the southwestern United States (Byrd 1978; Henny and Blus 1986), while those originating from central and eastern North America winter in all the other areas mentioned above (Byrd 1978).

Few studies have examined the seasonal distribution of Black-crowned Night-Herons that breed in Canada. Byrd (1978) reviewed the distribution of night-herons in North America during their first 12 months. Wolford and Boag (1971) reported on recoveries of birds banded in two colonies in Alberta. Brewer and Salvadori (1978) listed recoveries, during 1965-1970, of Ontario-banded birds. None of these authors studied seasonal distribution of Black-crowned Night-Herons after their first year of life.

In this paper, we analyze all recoveries of Black-crowned Night-Herons banded in Canada as of 31 December 1986 and attempt to determine patterns of migration and distribution in adult, yearling, and juvenile birds.

Methods and Materials

Banding and band recovery data were provided by the Canadian Wildlife Service (CWS) Bird Banding Office. There were 107 recoveries of birds from 1942 to 1986. All recoveries included birds that were banded in Quebec, Ontario, Manitoba, Saskatchewan, and Alberta (Figure 1).

Although recovery records date from 1942, neither the CWS Bird Banding Office nor the U.S. Fish and Wildlife Service Bird Banding Laboratory could provide us with banding records prior to 1955 due to a loss of data. During the 1955-1986 period, 3262 Black-crowned Night-Herons were banded in Quebec and Ontario, 754 were banded in the Prairie Provinces, and 31 were banded in New

Brunswick and Nova Scotia, none had been recovered as of 31 December 1986.)

We grouped Black-crowned Night-Herons into three different age groups according to date of recovery. Most night-herons begin to nest at 2-3 years of age (Palmer 1962; Hancock and Kushlan 1984). Although one-year-olds (12-24 months) will sometimes breed (Custer and Davis 1982), Cramp and Simmons (1977) mention that immatures are seldom seen near colonies. We thus designated two-year-old and older birds as adults, one-year-olds as yearlings, and younger birds as juveniles. A juvenile becomes a yearling and a yearling becomes an adult on 1 April. We chose this date because that month is the onset of nesting by Black-crowned Night-Herons in Canada and the northern United States (Bull 1974; Wood 1951 *in* Palmer 1962; Roberts 1932 *in* Palmer 1962; Wolford and Boag 1971).

Of the 107 recoveries, we could not use three because they were of birds banded at an unknown age and recovered in the same year. We also excluded four recoveries of juveniles found dead in the same block of 10′ latitude × 10′ longitude in which they were originally banded and one recovery in Quebec of a juvenile banded in the same province, for which no information on latitude and longitude was reported. This left 99 usable recoveries for analysis. Ninety-seven were of birds originally banded as chicks, while one was banded in a year after hatching and one was banded at an unknown age. The latter two recoveries occurred two or more years after banding, indicating adult birds at the time of recovery.

For each age group, we classified recoveries according to month of recovery. In the case of inexact date of recovery, we made the following assumptions: (1) a recovery during "summer" (N = 1) occurred within June to August, (2) a recovery during "winter" (N = 1) occurred within November to March, (3) a recovery during the "hunting season" (autumn) (N = 2) occurred within September and October, and (4) when the only date available was the date of the letter reporting the band recovery (N = 7), that date was deemed to be the recovery date.

Recovery locations are given by the CWS Bird Banding Office as the south-east corner of the block of 10′ latitude × 10′ longitude in which the recovery was obtained. We marked the recovery locations on maps by plotting them in the centres of these 10′ blocks. Two recovery locations were reported incompletely to the Bird Banding Office (i.e., the recovery location was given as a state or province). In both cases, we plotted the recovery in the centre of the given area.

Results and Discussion

Autumn and Winter Distribution

Fall migration occurs during September and October. Of birds banded in Ontario and Quebec, adults were recovered in both provinces and Ohio while juveniles were recovered in both provinces, Vermont, New York, New Jersey, Maryland, South Carolina, Alabama, Cuba, and Jamaica (Figure 2). There were no recoveries of yearlings.

Of birds banded in the Prairie Provinces, adults were recovered in Kansas and Oklahoma; yearlings in Manitoba and Illinois; and juveniles in Manitoba, Saskatchewan, and Nebraska (Figure 2).

Figure 3 shows the distribution of Black-crowned Night-Herons during winter, i.e. November through March. Of birds banded in Ontario and Quebec, adults were recovered in the Bahamas, Cuba, and the Dominican Republic (island of Hispaniola), yearlings were recovered in Cuba, and juveniles were recovered in Quebec, Ontario, Vermont, New York, Pennsylvania,

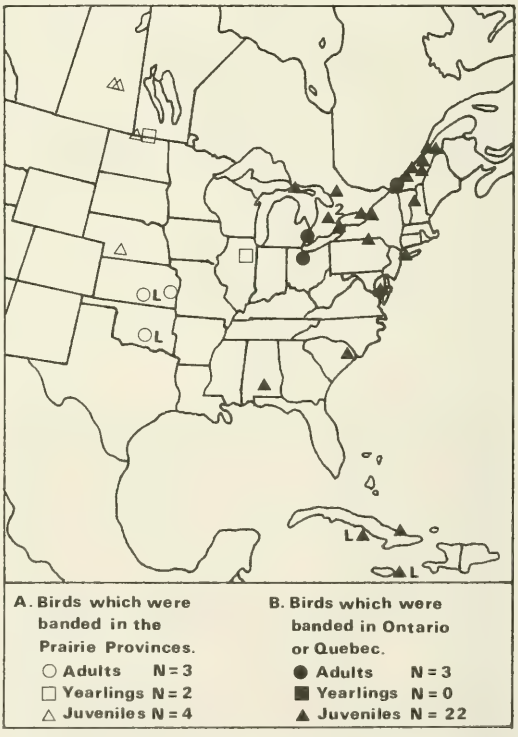
A. Birds which were banded in the Prairie Provinces.
○ Adults N = 3
□ Yearlings N = 2
△ Juveniles N = 4
B. Birds which were banded in Ontario or Quebec.
● Adults N = 3
■ Yearlings N = 0
▲ Juveniles N = 22

FIGURE 2. Band recoveries of Black-crowned Night-Herons during September-October, 1942-1986. Symbols with numbers indicate two or more recoveries in the same 10′ block. A symbol with the letter "L" indicates that the only date available was the date of the letter reporting this recovery. See methods and materials.

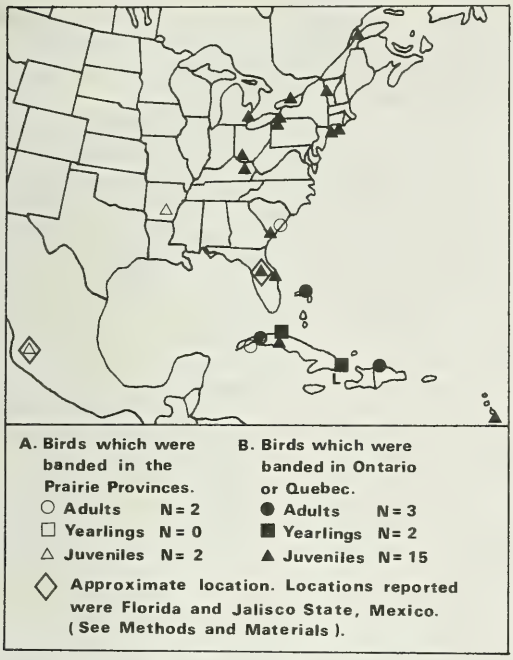
A. Birds which were banded in the Prairie Provinces.
○ Adults N = 2
□ Yearlings N = 0
△ Juveniles N = 2
B. Birds which were banded in Ontario or Quebec.
● Adults N = 3
■ Yearlings N = 2
▲ Juveniles N = 15
◇ Approximate location. Locations reported were Florida and Jalisco State, Mexico. (See Methods and Materials).

FIGURE 3. Band recoveries of Black-crowned Night-Herons during November-March, 1942-1986. A symbol with the letter "L" indicates that the only date available was the date of the letter reporting this recovery. See methods and materials.

Michigan, Ohio, Kentucky, South Carolina, Florida, Cuba, and the Lesser Antilles. Whereas adults may occur in Ontario and Quebec during September and October, all recoveries during the winter (November to March) were in a few Caribbean islands.

Of birds banded in the Prairie Provinces, adults were recovered in South Carolina and Cuba, and juveniles were recovered in Arkansas and western Mexico (Figure 3). There were no recoveries of yearlings.

Recoveries of Prairie Province adults in South Carolina and Cuba during winter may indicate that these birds use the same wintering areas as Ontario and Quebec birds; i.e., the Caribbean islands and the southeastern Atlantic and Gulf Coast states. This pattern parallels recoveries of birds in their first year of life. Byrd (1978) concluded that first-year Black-crowned Night-Herons from the Prairie Provinces and Ontario and Quebec wintered in the southeastern Atlantic and Gulf Coast states and the Caribbean islands as well as Mexico. He suggested that birds from Ontario and Quebec generally move south towards the southern Atlantic and Gulf coasts, while those from the Prairie Provinces followed the Mississippi drainage to reach the Gulf of Mexico and the south Atlantic states. Once in these areas, they would reach the Caribbean islands via Florida.

For birds banded in the United States, Byrd (1978) noted that the migratory pattern in the eastern states differed from that of states west of the Mississippi drainage. Juveniles from colonies in the northeastern Atlantic states, the eastern Great Lakes states, Pennsylvania, Ohio, and Indiana generally moved south towards the southern Atlantic and Gulf Coasts, and then on to the Caribbean Islands. Many juveniles from the western Great Lakes states and states to the west and northwest of the Mississppi drainage would follow it to the Gulf of Mexico and the southern Atlantic states and reach the Caribbean Islands via Florida while others would move south to Texas and then migrate into Mexico and Central America.

Figures 2 and 3 show that juvenile migration is probably not as directional as that of adults and yearlings. Although juveniles have been recovered as early as 18 September on the adult and yearling winter range, others have been recovered from Gaspé, Quebec (January), the north shore of Lake Ontario (November), Michigan (November), Ohio (December), New York (December), Long Island (December and February), Pennsylvania (December), Vermont (March), and Kentucky (November). Five of the 10 recoveries were birds found dead, two were shot, one was caught due to an injury, one was caught due to disease, and the condition of the remaining bird was unknown. Most of these birds probably succumbed to hunting or winter weather during the November to March period. These recoveries are more indicative of fall migratory routes than wintering sites for juveniles.

The one recovery in western Mexico (Figure 3) was of a juvenile originally banded in Alberta. Recovery data showed only three birds banded in Alberta. Besides the one in Mexico, a juvenile was recovered in Nebraska (Figure 2) and an adult was found in Cuba (Figure 3). All three recoveries were reported by Wolford and Boag (1971). The two in Nebraska and Cuba were of birds banded as nestlings in the same colony near the town of Cassils in southern Alberta (Figure 1). However, the juvenile recovered in Mexico was banded in a colony near Rainier, about 24 km south of the Cassils colony. As shown in Figure 1, the two large breeding ranges in North America are divided into a western area and an "eastern" area. Alberta is included in the eastern breeding range. However, Henny and Blus (1986) have shown that birds breeding in the northern part (Idaho and Oregon) of the western breeding range winter on both the east and west coasts of Mexico, with the majority occurring along the west coast.

It is possible that birds in the Rainier colony of Alberta originated from the western breeding range while those in the Cassils colony are in the eastern range. Alternatively, the Rainier juvenile may simply have taken a different route than normal, perhaps in the company of some western birds. Black-crowned Night-Herons will migrate singly (Cramp and Simmons 1977) or in small to large flocks (Palmer 1962; Cramp and Simmons 1977).

Spring and Summer Distribution (Site Tenacity)

Of birds banded in Ontario and Quebec, there were 19 recoveries of adults during April through August, 1942-1986 (Figure 4). Thirteen recoveries in Ontario and Quebec were of birds recovered in the same province where they had been banded as chicks. Two recoveries occurred in the same 10′ banding block.

Six recoveries were within 20 km of the original banding location (including the two within the same banding block) while 12 occurred from 90 to 800 km ($\bar{x}$ = 190 km) of the banding location. In addition, one recovery from Cuba, not fitting this pattern (> 2000 km from the banding location), consisted of a report of only the band or band number and the only date available was the date of the letter reporting the recovery.

A. Birds which were banded in the Prairie Provinces.
○ Adults N = 1
□ Yearlings N = 0

B. Birds which were banded in Ontario or Quebec.
● Adults N = 19
■ Yearlings N = 8

◆ Locations where adults and yearlings were recovered in the same 10′ block. E.g. 1a indicates one recovery of an adult, 2y indicates two recoveries of yearlings.

FIGURE 4. Band recoveries of Black-crowned Night-Herons during April-August, 1942-1986. Juveniles (N = 0, Prairie Provinces; N = 13, Ontario and Quebec) are not plotted. See text. A symbol with the letter "L" indicates that the only date available was the date of the letter reporting this recovery. See methods and materials.

There were eight recoveries of yearlings from April to August (Figure 4). Four of these were recoveries in the same 10′ block of the original banding: two were birds found dead, one was a bird caught in a trap other than that used for catching birds, and the fourth was a report of a band or band number only. It is possible that most of these recoveries were birds that died the previous fall and winter and then were discovered by bird banders during the spring and summer. Of the remaining four recoveries, three were birds found dead and one was shot. Seven of the eight April-August recoveries occurred within 250 km ($\bar{x}$ = 60 km) of the original banding location. The remaining one was an exception in that a bird was found dead in Florida (> 1600 km from the banding location) on 2 April. This bird had probably wintered in Florida and may have died before April.

Even if some recoveries were birds that died the previous year, the remaining ones show that yearlings may have the same degree of tenacity to natal colony as adults, i.e. the majority of recoveries occurred within 250 km of the banding location. Our findings disagree with Byrd's (1978) suggestion that adults will establish nesting sites far from their natal colonies. In fact, he cites an example of Saskatchewan-banded birds being recovered on the Atlantic Coast during the breeding season. Our analysis of all Saskatchewan-banded birds showed no recoveries of adults during April through August and only one recovery on the Atlantic Coast (South Carolina, in February) (Figure 3). [Unfortunately, we were unable to contact M. A. Byrd]. In May 1967, a Manitoba-banded chick was recovered as an adult in North Dakota (Figure 4), only 225 km southeast of its banding location. This was the only recovery of a Prairie Province bird during April to August, 1942-1986.

There were 12 recoveries of juveniles in August and one in July for a total of 13 during the summer. All were of birds banded in Ontario and Quebec and all occurred from 20 to 850 km of the original banding locations. Only three recoveries occurred beyond the natal province. Two were of juveniles originally banded in Ontario, recovered in New York and Quebec, and one was of a juvenile banded in Quebec and recovered in northern New York. Although juveniles disperse in all directions after the breeding season (Cramp and Simmons 1977; Byrd 1978), we did not note significant southward movements until September when recoveries were reported from Alabama and New Jersey (Figure 2).

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Denning Behavior of Black Bears, *Ursus americanus*, in Western Manitoba

WALT KLENNER[1] and DARRYL W. KROEKER

Department of Zoology, University of Manitoba, Winnipeg, Manitoba R3T 2N2
[1]Present address: Department of Zoology, University of British Columbia, Vancouver, British Columbia V6T 2A9

Klenner, Walt, and Darryl W. Kroeker. 1990. Denning behavior of Black Bears, *Ursus americanus*, in western Manitoba. Canadian Field-Naturalist 104(4): 540–544.

Denning habits of Black Bears, *Ursus americanus*, were studied in western Manitoba from May 1979 to April 1981. Of 25 dens examined, 23 were excavated and all but one contained nesting material. Black Bears constructed dens in all major habitat types found in the study area. Females constructed dens within the confines of their summer range. Subadult males often utilized den sites in the Duck Mountain Provincial Forest after an abrupt move of 20-42 km away from their summer activity center.

Key Words: Black Bear, *Ursus americanus*, denning behavior, western Manitoba.

Black Bears (*Ursus americanus*) utilize dens during winter dormancy across much of their range in North America. Den sites have included open ground nests, enlarged tree cavities and excavated burrows (Beecham et al. 1983; Erickson et al. 1964; Pelton et al. 1980; Tietje and Ruff 1980). Selection of specific habitats in which to construct dens has not been widely reported. LeCount (1983) noted that Black Bears in Arizona selected Chaparral, while Beecham et al. (1983) noted that concealment appeared to be a factor in the selection of den sites in Idaho. Undisturbed dens are important since harassment may lead to increased overwinter weight loss and abandonment of cubs (Smith 1946; Tietje and Ruff 1980). We compared the types and location of dens used by male and female Black Bears in an area of mixed deciduous-coniferous forest and agricultural lands.

Study Area

The study was conducted from May 1979 to April 1981 in west-central Manitoba (51° 37′N, 100° 35′W) along the eastern boundary of the Duck Mountain Provincial Forest. Wide seasonal fluctuations in temperature occur with mean January and July temperatures of -19 and +19°C respectively. Mean annual snowfall is 120 cm and the 1 November to 15 April period usually has snow accumulations exceeding 10 cm (Environment Canada; Dauphin, Manitoba).

Vegetation in the Duck Mountain Provincial Forest is primarily mixed coniferous-deciduous forest with Aspen (*Populus tremuloides*), Balsam Poplar (*P. balsamifera*), White spruce (*Picea glauca*), and Balsam Fir (*Abies balsamea*) forming the dominant overstory associations. Jack Pine (*Pinus banksiana*) and Black Spruce (*P. mariana*) occur in sandy uplands and poorly drained areas, respectively. Common mast producing shrubs include Beaked Hazel (*Corylus cornuta*), Highbush Cranberry (*Viburnum opulus*), Serviceberry (*Amelanchier alnifolia*), and several cherry species (*Prunus* spp.).

Where undisturbed, vegetation in the agricultural area was similar to that in the adjacent Provincial Forest. The amount of cleared farmland was highly variable on individual farms, ranging from 90% to less than 5% on farms used as woodlots. Predominant agricultural practices include the production of livestock and raising of forage and cereal crops.

Methods

Bears were captured with Aldrich leg snares using techniques similar to those outlined by Johnson and Pelton (1980). Bears were immobilized with a combination of ketamine hydrochloride (Ketaset, Rogar-STB) and xylazine hydrochloride (Rompun, Bayvet) in a 2:1 ratio administered intramuscularly by a jab-pole syringe (Addison and Kolenosky 1979). Animals were classified as yearlings (1-2 years), subadults (2-4 years) and adults (> 4 years) based on counts of cementum annuli. Twenty-five bears were equipped with radio-transmitters (Model 5B, Telonics, Mesa, Arizona).

Den sites of radio-collared bears were located after they became inactive in October or early November. Habitat characteristics of the area surrounding the den site were evaluated in winter and dens were examined after bears had departed in spring.

The summer range was estimated by the minimum convex polygon (Mohr 1947) after 10% of the outermost locations were deleted. Summer (11 July-15 September 1979, 16 June-31 August 1980) was characterized by the presence of ripe

mast and berries. The geometric center of summer location data was used to estimate the activity center of the summer range. An average of 14 locations was used to delineate the summer range and activity center in 1979. Increased monitoring effort in 1980 allowed us to estimate the summer range and activity center with an average of 59 locations. To reduce bias in the estimate of summer range size and dimensions, all animals were located when searched for in 1980.

Results

During the two years of observation, 27 dens were located, of which 25 were examined. Of 16 female and 6 male bears fitted with radio transmitters, the dens of only 5 (3 female, 2 male) were examined during both years because of a high mortality rate (due to hunting and trapping) of the animals being monitored. Of the 16 bears fitted with radio-collars in 1979, 50% of the animals had been killed by September 1980 (3 of 6 males, 5 of 10 females).

In 1979, three subadult males moved abruptly ($\bar{x}$ = 33.3 km, SE = 6.8) away from the summer activity center between 3 and 16 October (Figure 1). Before this move, we located these animals once or twice a week and they had not made wide-ranging movements. During early October, we

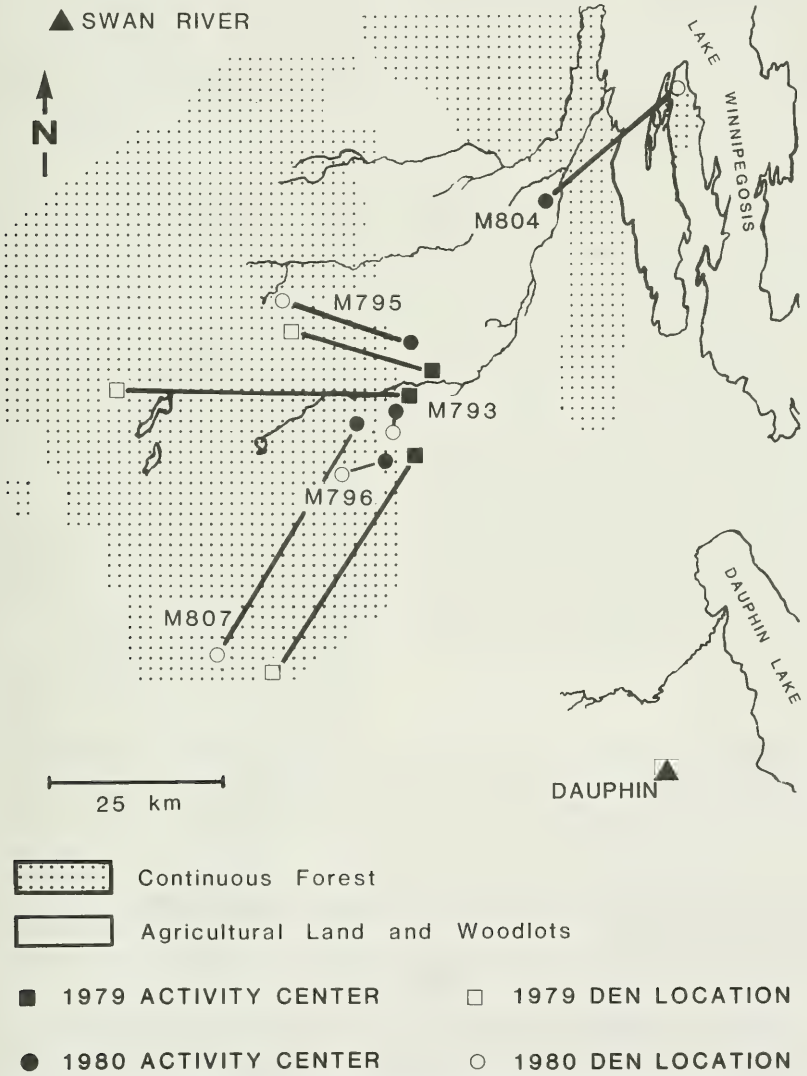

FIGURE 1. The relationship between the summer activity center and den locations of subadult male Black Bears monitored in western Manitoba during 1979 and 1980.

were unable to locate these animals and an aerial search was used to locate the den sites. A yearling male used a den within 0.5 km of its summer activity center and the adult male being monitored moved 7.3 km to the west of its summer activity center to construct a den. One subadult male which moved 19.8 km away from its summer activity center to a den site in 1979 followed a similar pattern in 1980. Two other subadult males denned close (1.4 and 5.8 km) to their summer activity center in 1980 (Figure 1). A fourth subadult male, monitored since June 1980, denned 38.5 km from its summer activity center after an abrupt move during the first week of October. Subadult males always used den sites to the west of their summer activity center but females showed no preference for a specific direction. By moving westward to a den site, subadult males denned within the Duck Mountain Provincial Forest on all occasions. Upon emergence in April 1980, two males returned directly to the vicinity of their 1980 summer activity center whereas a third animal returned by a circuitous route.

In contrast, females did not exhibit abrupt movements from their summer activity center before denning. In 1979 and 1980, two subadult females moved to the western edge of their summer range before denning but other females did not show this pattern (Table 1, Figure 2). Females did not construct dens beyond the periphery of their summer ranges in 1979 or 1980. Five females constructed dens in or within 100 m of an open field and three others denned within 200 m of a heavily travelled road. This behavior suggests little avoidance of areas of frequent human activity.

Dens were located within all major habitat types found in the study area including Aspen-White Spruce, Black Spruce, Jack Pine, dense brush along streams, and open fields. In spite of the reduced forest cover on the agricultural lands, bears readily used dens within 300 m of farmyards and within 25 m of the edge of fields. No instance of den reuse was observed, although local trappers reported that dens were occasionally reoccupied in subsequent years.

Only 2 of 25 dens examined were constructed without excavation. Nine dens were excavated under the roots of standing or partially blown-down trees and six were excavated into hillsides or a riverbank. Seven were dug in areas with no relief. Two dens were located in bulldozed brush piles in fields and one consisted of a shallow grass-lined depression under some shrubs.

All nest chambers except one were lined with grass, moss, leaf litter or twigs. A subadult female that moved to her den site one day before snowfall did not have lining material in the den. Although we did not quantify the nesting material used, we did not observe any obvious differences in the type or quantity of nesting material in the dens of yearlings, subadult or adult animals, or between males and females. Dens near open fields or farmyards were located in dense brush or among fallen trees.

There was a tendency for bears to den earlier in 1980 (23 September-12 November) than in 1979 (10 October-15 November) but the difference was not significant. In 1980, four adult females entered dens between 23 September and 7 October, whereas several subadults remained active until 12 November. Necropsies of animals killed during the summer suggested that adults were in better condition in 1980, accumulating more than 10 cm of subcutaneous fat dorsally by mid-August (n = 4). In 1979, mast and berries were scarce until a large crop of High-bush Cranberry ripened in September and remained on the bushes into winter. The fat levels of bears necropsied in late June and July 1979 were less than four cm (n = 6) and reflect the scarcity of natural food in early summer. In 1980, Serviceberries were very abundant until early September, after which there

TABLE 1. Dimensions of the summer range and distance to the den site for Black Bears monitored in 1980.

Cohort	n	Major Axis (km) $\bar{X}$	Major Axis (km) SE	Minor Axis (km) $\bar{X}$	Minor Axis (km) SE	*A mean radius of summer range	B Mean distance from summer activity center to den	Ratio B:A
Adult female	6	6.9	0.6	5.1	0.7	3.0	2.1	0.7
Subadult female	6	7.6	1.2	3.6	0.8	2.8	2.8	1.0
Adult male	1	72.8		32.3		26.3	26.5	1.0
Subadult male	4	16.7	6.9	10.2	4.9	6.7	16.4	2.4

*calculated as $\left(\frac{\text{radius of major axis + radius of minor axis}}{2}\right)$

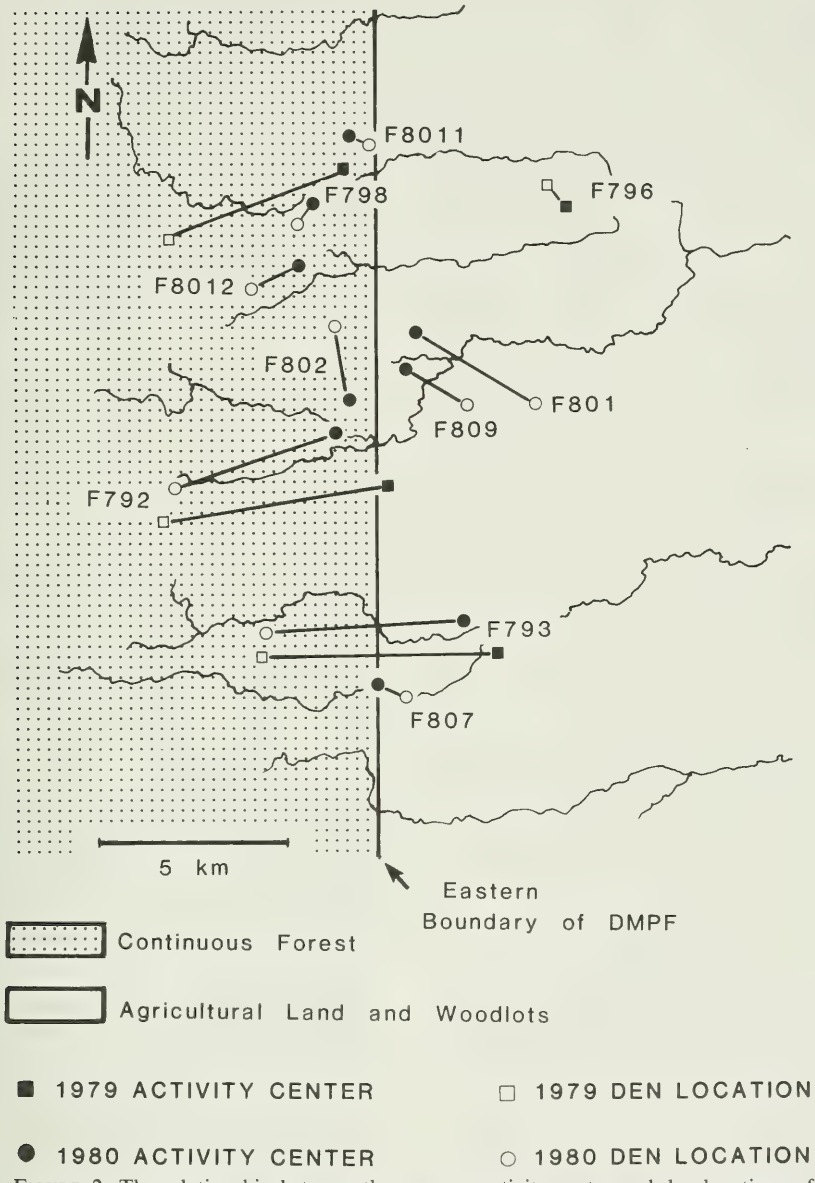

FIGURE 2. The relationship between the summer activity center and den locations of female Black Bears monitored in western Manitoba during 1979 and 1980 along the eastern boundary of Duck Mountain Provincial Forest (DMPF).

was little mast or berries available. These results suggest that the onset of dormancy may be affected by body condition, age and food availability.

Discussion

Pelton et al. (1980) and Rogers (1977, 1987) noted that most bears returned from foraging areas as far as 174 km away to their mating or summer ranges to construct dens. Tietje and Ruff (1980) indicated a similar trend for females but reported males often used a den site far removed from the summer range. In western Manitoba, subadult males often denned beyond summer ranges after an abrupt move in mid-autumn. The significance of using a remote den site is difficult to determine because the history of these animals was not known. However, the move away from the summer range in autumn and direct return in spring by two

males suggests the use of remote dens was not a dispersal movement or a random search for a den site. The ability of females to locate suitable dens within the confines of their summer range suggests that the availability of den sites is not an important factor in the use of a remote den by subadult males. The tendency of subadult males to use a den site closer to their summer activity centers in 1980 may reflect changes in the social status of these animals or simply a change in local food availability. The small number of animals being monitored combined with the loss of two of the four subadult males being monitored to hunters precludes definite conclusions. In contrast to the pattern shown by subadult males, females always utilized den-sites within their summer range. This finding supports reports by Rogers (1977, 1987), Fuller and Keith (1980), and Tietje and Ruff (1980). These authors reported a tendency for females to den near the periphery of their home ranges but this was not observed in the present study.

Dens examined in this study were similar to those reported by Tietje and Ruff (1980) who suggested that the type of den used is related to winter severity. Since large hollow trees are not common in the boreal forest, excavated and lined burrows are utilized as protection from severe winters. Because winters in Manitoba and Alberta are of approximately the same severity, data from our study support this hypothesis. The pattern of den entry we observed is consistent with that reported by Rogers (1987). In 1980, bears in our study area had large fat reserves by late August and began to enter dens in September. Poor fat reserves combined with a large crop of High-bush Cranberry which began to ripen in September resulted in later den entry dates in 1979.

The use of dens in a wide range of habitats and in areas close to potential disturbances along with the low incidence of den reuse suggests that the availability of den sites does not limit this population.

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Diets of Nesting Bald Eagles, *Haliaeetus leucocephalus*, in Western Washington

RICHARD L. KNIGHT[1,2] PHILIP J. RANDOLPH,[1,3] GEORGE T. ALLEN,[1,4]
LEONARD S. YOUNG,[5] and REBECCA J. WIGEN[6]

[1]Washington Department of Wildlife, 600 N. Capitol Way, Olympia, Washington 98504
[2]Present address: Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado 80523
[3]Present address: E. 3909 Beverly Rd., Mead, Washington 99021.
[4]U.S. Fish and Wildlife Service, 1501 14th St. West, Suite 230, Billings, Montana 59102
[5]Washington Department of Natural Resources, Forest Land Management Division, MQ-11, Olympia, Washington 98504
[6]Department of Anthropology, University of Victoria, P.O. Box 1700, Victoria, British Columbia V8W 2Y2

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We analyzed food remains collected at Bald Eagle (*Haliaeetus leucocephalus*) nests from three regions in Washington: San Juan Islands, Olympic Peninsula, and Puget Sound. Of 1198 items collected, 53% were birds, 34% were fish, 9% were mammals, and 4% were invertebrates. Fish were more abundant at nests in the San Juan Islands and Puget Sound than at nests on the Olympic Peninsula. Overall, mammals were not important; however, the Old World Rabbit (*Oryctolagus cuniculus*) was a common food species for eagles in the San Juan Islands. Forty-two prey items were identified during 212 hours of direct observations at three eagles nests. This allowed a comparison of prey delivered to nests with prey found beneath these nests and indicated that birds were over-represented in prey collections beneath nests and fish were over-represented in prey carried to nests. Two important Bald Eagle food items, the Glaucous-winged Gull (*Larus glaucescens*) and Old World Rabbits (*Oryctolagus cuniculus*) were analyzed for DDE and PCBs; the former showed detectable levels of both.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, Washington, food habits.

The Pacific Northwest region of North America has the largest population of both nesting and wintering Bald Eagles within the species' range (Stalmaster 1987). Diets of wintering Bald Eagles in this region are well known (Stalmaster et al. 1985), but information on summer diets is either anecdotal or from studies of localized areas (Murie 1940; Imler and Kalmbach 1955; Retfalvi 1970; Ofelt 1975; Sherrod et al. 1976; Grubb and Hensel 1978; Van Daele and Van Daele 1980). Our objectives were to identify the food items of nesting Bald Eagles in Washington, to evaluate differences in food habits among three distinct geographical areas within it, and to compare two methods of diet evaluation. Finally, because Bald Eagles in the Pacific Northwest contain environmental contaminants, we examined two important prey species for DDE and PCB concentrations.

Study Area and Methods

Between 8 April-21 June 1980 and 4 June-30 July 1981, we collected prey remains below 102 nests in 68 nesting territories in western Washington. Collections were made from 34 territories on the San Juan Islands, and 17 territories each on the Olympic Peninsula and along Puget Sound. The San Juan Islands included all islands north of Whidbey Island and west of the mainland to the Canadian border (Figure 1 *in* Grubb 1976). The Olympic Peninsula included the coastline from Port Townsend west along the Strait of Juan de Fuca, around Cape Flattery, and south along the Pacific Coast to the north edge of Grays Harbor. Puget Sound included Puget Sound proper from Port Townsend south, plus Camino and Whidbey Islands and the mainland coast north to Canada.

Nests were visited just once during our study, and our visits fell within the normal nesting period of Bald Eagles (Stalmaster 1987: 63). Timing of our visits were balanced for each of the three areas. Prey remains were collected from the base of nest trees and adjacent perch trees. Prey remains were identified to the lowest taxon by comparison with museum specimens. The minimum number of individuals of each taxon in each collection was used to determine diet composition. We could not discount the possibility that some of the prey items we collected were from time periods other than the breeding season, including previous breeding seasons. Additionally, we have no way of confirming that all species listed as prey (Table 1) were indeed food items of Bald Eagles. For example, some of the invertebrates (e.g., snails) may have been in the intestines of eagle prey items.

Collections of Bald Eagles food remains may be biased in favor of items with conspicuous or

TABLE 1. Occurrence of food items collected under Bald Eagle nests and perch trees at three areas in in western Washington between April 1980 and August 1981.

Food Item	San Juan Islands				Olympic Peninsula				Puget Sound			
	Individuals[a]		Territories[a]		Individuals		Territories		Individuals		Territories	
Birds (Aves)	N	%	N	%	N	%	N	%	N	%	N	%
Western Grebe (*Aechmophorus occidentalis*)	55	6.0	19	55.9	11	7.3	11	64.7	14	10.4	9	52.9
Common Murre (*Uria aalge*)	49	5.3	24	70.6	26	17.2	10	58.8	12	8.9	6	35.3
Glaucous-winged Gull (*Larus glaucescens*)	37	4.1	16	47.0	3	2.0	3	17.6	3	2.2	3	17.6
Gull (*Larus* spp.)	31	3.4	14	41.2	4	2.6	3	17.6	1	tr[b]	1	5.9
Pelagic Cormorant (*Phalacrocorax pelagicus*)	27	2.9	19	55.9	9	6.0	6	35.3				
Grebe (*Podicipedidae*)	26	2.8	12	35.3	5	3.3	4	23.5	2	1.5	2	11.8
White-winged Scoter (*Melanitta fusca*)	18	1.9	14	41.2	8	5.3	6	35.3	5	3.7	5	29.4
Duck (*Anatidae*)	16	1.7	10	29.4	2	1.3	2	11.8	7	5.1	5	29.4
Rhinoceros Auklet (*Cerorhinca monocerata*)	16	1.7	9	26.5	5	3.3	5	29.4	2	1.5	2	11.8
Cormorant (*Phalacrocorax* spp.)	14	1.5	12	35.3	1	tr	1	5.9				
Brandt's Cormorant (*Phalacrocorax penicillatus*)	11	1.2	8	23.5	2	1.3	2	11.8				
Pigeon Guillemot (*Cepphus columba*)	10	1.1	7	20.6	1	tr	1	5.9	2	1.5	2	11.8
Duck (*Anas* spp.)	9	1.0	7	20.6	1	tr	1	5.9	1	tr	1	5.9
Surf Scoter (*Melanitta perspicillata*)	9	1.0	6	17.6	4	2.6	3	17.6	3	2.2	3	17.6
Red-breasted Merganser (*Mergus serrator*)	9	1.0	8	23.5								
Mallard (*Anas platyrhynchos*)	5	tr	4	11.8	1	tr	1	5.9	1	tr	1	5.9
Greater Scaup (*Aythya marila*)	5	tr	5	14.7					1	tr	1	5.9
Bufflehead (*Bucephala albeola*)	5	tr	5	14.7								
Western Gull (*Larus occidentalis*)	5	tr	3	8.8								
Scaup (*Aythya* spp.)	5	tr	4	11.8	1	tr	1	5.9				
Brant (*Branta bernicla*)	4	tr	2	5.9								
Common Merganser (*Mergus merganser*)	4	tr	3	8.8								
Crow (*Corvus* spp.)	4	tr	4	11.8	1	tr	1	5.9				
Red-throated Loon (*Gavia stellata*)	3	tr	2	5.9	1	tr	1	5.9				
Horned Grebe (*Podiceps auritus*)	3	tr	3	8.8								
Red-necked Grebe (*Podiceps grisegena*)	3	tr	3	8.8	1	tr	1	5.9				
California Gull (*Larus californicus*)	3	tr	2	5.9	2	1.3	2	11.8	1	tr	1	5.9
American Crow (*Corvus brachyrhynchos*)	3	tr	3	8.8	1	tr	1	5.9				
Northwestern Crow (*Corvus caurinus*)	3	tr	2	5.9								
Common Raven (*Corvus corax*)	3	tr	3	8.8								
Duck (*Bucephala* spp.)	3	tr	3	8.8	1	tr	1	5.9				
Arctic Loon (*Gavia arctica*)	2	tr	2	5.9					2	1.5	1	5.9
Common Loon (*Gavia immer*)	2	tr	2	5.9								
Great Blue Heron (*Ardea herodias*)	2	tr	1	2.9	1	tr	1	5.9	2	1.5	1	5.9
Northern Pintail (*Anas acuta*)	2	tr	2	5.9								

TABLE 1. (continued).

Food Item	San Juan Islands				Olympic Peninsula				Puget Sound			
	Individuals[a]		Territories[a]		Individuals		Territories		Individuals		Territories	
Birds (Aves) continued	N	%	N	%	N	%	N	%	N	%	N	%
American Wigeon (*Anas americana*)	2	tr	2	5.9					1	tr	1	5.9
Common Goldeneye (*Bucephala clangula*)	2	tr	2	5.9								
Turkey (*Meleagridinae*)	2	tr	2	5.9								
Herring Gull (*Larus argentatus*)	2	tr	1	2.9								
Pileated Woodpecker (*Dryocopus pileatus*)	2	tr	2	5.9	1	tr	1	5.9				
Pied-billed Grebe (*Podilymbus podiceps*)	1	tr	1	2.9								
Canada Goose (*Branta canadensis*)	1	tr	1	2.9	2	1.3	1	5.9				
Lesser Scaup (*Aythya affinis*)	1	tr	1	2.9								
Oldsquaw (*Clangula hyemalis*)	1	tr	1	2.9								
Hooded Merganser (*Lophodytes cucullatus*)	1	tr	1	2.9								
Bonaparte's Gull (*Larus philadelphia*)	1	tr	1	2.9								
Black-legged Kittiwake (*Rissa tridactyla*)	1	tr	1	2.9	1	tr	1	5.9				
Band-tailed Pigeon (*Columba fasciata*)	1	tr	1	2.9								
Belted Kingfisher (*Ceryle alcyon*)	1	tr	1	2.9								
Grouse (Tetraoninae)	1	tr	1	2.9								
Scoter (*Melanitta* spp.)	1	tr	1	2.9	4	2.6	1	5.9				
Red-tailed Hawk (*Buteo jamaicensis*)	1	tr	1	2.9								
Merganser (*Mergus* spp.)	1	tr	1	2.9								
Sooty Shearwater (*Puffinus griseus*)					6	4.0	4	23.5				
Alcid (Alcidae)	3	tr	2	5.9	2	1.3	2	11.8	2	1.5	1	5.9
Shearwater (*Puffinus* spp.)					2	1.3	2	11.8				
Northern Fulmar (*Fulmarus glacialis*)					1	tr	1	5.9				
Varied Thrush (*Ixoreus naevius*)					1	tr	1	5.9				
Gadwall (*Anas strepera*)									2	1.5	1	5.9
Ring-necked Pheasant (*Phasianus colchicus*)									3	2.2	2	11.8
Rock Dove (*Columba livia*)									1	tr	1	5.9
Unidentified	7	tr	7	20.6	4	2.6	4	23.5	7	5.1	7	41.2
Bird Subtotal	439	48.2			116	77.5			76	56.3		
Fish (Osteichthyes)												
Rockfish (*Sebastes* spp.)	134	14.7	26	76.5	11	7.2	5	29.4	8	5.9	6	35.3
Ling-cod (*Ophiodon elongatus*)	52	5.7	16	47.1	9	6.0	6	35.3	2	1.5	1	5.9
Walleye Pollock (*Theragra chalcogramma*)	36	3.9	14	41.2					1	tr	1	5.9
Pacific Hake (*Merluccius productus*)	34	3.7	11	32.3					2	1.5	2	11.8
Pacific Cod (*Gadus macrocephalus*)	21	2.3	9	26.5					1	tr	1	5.9
Cabezon (*Scorpaenichthys marmoratus*)	20	2.2	8	23.5	1	tr	1	5.9	1	tr	1	5.9

TABLE 1. (continued).

Food Item	San Juan Islands				Olympic Peninsula				Puget Sound			
	Individuals[a]		Territories[a]		Individuals		Territories		Individuals		Territories	
Fish (Osteichthyes) continued	N	%	N	%	N	%	N	%	N	%	N	%
Red Irish Lord (*Hemilepidotus hemilepidotus*)	10	1.1	5	14.7	1	tr	1	5.9	2	1.5	2	11.8
Great Sculpin (*Myoxocephalus polyacanthocephalus*)	8	tr	8	23.5					4	2.9	2	11.8
Buffalo Sculpin (*Enophrys bison*)	5	tr	2	5.9								
Starry Flounder (*Platichthys stellatus*)	4	tr	3	8.8					10	7.4	5	29.4
True Cod (*Gadidae*)	3	tr	3	8.8					2	1.5	1	5.9
Surf Perch (Embiotocidae)	3	tr	3	8.8	1	tr	1	5.9	1	tr	1	5.9
Salmon (*Oncorhynchus* spp.)	1	tr	1	2.9					1	tr	1	5.9
Sculpin (Cottidae)	1	tr	1	2.9					1	tr	1	5.9
English Sole (*Parophrys vetulus*)	1	tr	1	2.9								
Prickleback (Stichaeidae)	1	tr	1	2.9								
Steelhead (*Salmo gairdneri*)									1	tr	1	5.9
Plainfin Midshipman (*Porichthys notatus*)									2	1.5	1	5.9
Channel Catfish (*Ictalurus punctatus*)									6	4.4	1	5.9
Flatfish (Pleuronectiformes)	1	tr	1	2.9								
Fish (Chondrichthyes)												
Spiny Dogfish (*Squalus acanthias*)	1	tr	1	2.9								
Spotted Ratfish (*Hydrolagus colliei*)	1	tr	1	2.9								
Fish Subtotal	337	36.9			23	15.2			45	33.3		
Mammals (Mammalia)												
Old World Rabbit (*Oryctolagus cuniculus*)	88	9.6	19	55.9								
Black-tailed Deer (*Odocoileus hemionus*)	3	tr	3	8.8	1	tr	1	5.9	1	tr	1	5.9
Domestic Cow	3	tr	3	8.8								
Raccoon (*Procyon lotor*)	2	tr	2	5.9	1	tr	1	5.9				
Muskrat (*Ondatra zibethicus*)	1	tr	1	2.9								
Weasel (*Mustela* spp.)	1	tr	1	2.9								
Domestic Sheep	1	tr	1	2.9								
Mountain Beaver (*Aplodontia rufa*)					1	tr	1	5.9				
Snowshoe Hare (*Lepus americanus*)									1	tr	1	5.9
Rabbit (*Leparidae*									3	2.2	3	17.6
Mammal Subtotal	99	10.8			3	2.0			5	3.7		
Invertebrates												
Abalone (*Haliotis kamtschatkana*)	17	1.9	4	11.8								
Limpet (*Acmaea* spp.)	1	tr	1	2.9								
Snail (*Lunatia pallida*)	1	tr	1	2.9								
Snail (*Nucella lamellosa*)	1	tr	1	2.9	2	1.3	1	5.9				
Snail (*Amphissa columbiana*)	1	tr	1	2.9								

TABLE 1. (concluded).

Food Item	San Juan Islands				Olympic Peninsula				Puget Sound			
	Individuals[a]		Territories[a]		Individuals		Territories		Individuals		Territories	
Invertebrates continued	N	%	N	%	N	%	N	%	N	%	N	%
Mussel (*Mytilus edulis*)									3	2.2	2.11.8	
Scallop (*Chlamys hastata*)	1	tr	1	2.9								
Bivalve (*Clinocardium nutalli*)	3	tr	3	8.8	1	tr	1	5.9	1	tr	1	5.9
Clam (*Macoma inquinata*)									1	tr	1	5.9
Bivalve (*Protothaca staminea*)	5	tr	4	11.8	4	2.6	2	11.8	1	tr	1	5.9
Clam (*Saxidomus gigantea*)									2	1.5	1	5.9
Bivalve (*Mya arenaria*)					1	tr	1	5.9				
Piddock (*Zirfaea pilsbryi*)									1	tr	1	5.9
Snail (*Vespericola columbiana*)	1	tr	1	2.9								
Snail (*Monodenia fidelis*)	5	tr	4	11.8								
Invertebrate Subtotal	36	3.9			8	5.3			9	6.7		
GRAND TOTAL	911	100.0	34		150	100.0	17		135	100.0	17	

[a]"Individuals" refers to number of prey items; "territories" refers to the number of eagle territories in which the prey item was found.
[b]tr = < 1.0%.

unpalatable body parts (Todd et al. 1982). To examine the extent of this bias in our study, we compared diet determined by observing food items brought to three nests containing young with diet determined by collecting remains beneath the nest trees. Nest observations were made in the San Juan Islands between 2 June and 9 July 1980 and observation effort was evenly allocated among times of day and nest sites. Prey collections beneath nests were made in July 1980. Prey items were identified to class using a 15-60X telescope from a blind 160-570 m from each nest tree. We tested for differences among data collection methods for variations in diet using chi-square analysis.

Nine Glaucous-winged Gulls (scientific names appear in Table 1) and four Old World Rabbits were collected on San Juan Island on 22 and 23 June 1980. Gulls were weighed whole, then liver, breast muscle, and heart were removed and frozen for chlorinated hydrocarbon analysis. Rabbits were weighed whole, then livers were dissected for analysis. Chemical contaminants were analyzed according to Stanley and LeFavoure (1965), Murphy (1972), and Webb and McCall (1973).

Results and Discussion

Regional diet composition

We collected 1198 food items representing 83 prey species: 49 species of birds, 15 species of fish, 8 species of mammals, and 14 species of invertebrates (Table 1). The diet of Bald Eagles as measured by the frequency of occurrence of individuals in major food classes varied regionally ($\chi^2 = 56.9$, df = 6, $P < 0.001$; Figure 1). Birds comprised 78% of all prey remains at Olympic Peninsula nests; more fish and fewer birds were found at territories in the San Juan Islands. Mammals comprised 11% of total prey items in the San Juan Islands, which was much higher when compared to the other regions ($\chi^2 = 167.2$, df = 1, $P < 0.001$).

At nests in the San Juan Islands, grebes, murres, gulls, and cormorants were the most important avian prey items, both in terms of numbers and biomass, occurring in over half of all territories (Table 1). Rockfish, Ling-cod, Walleye Pollock, and Pacific Hake were the most important fish prey species and were found on at least 75% of all territories. The Old World Rabbit comprised 89% of all mammalian foods items and were found on over half of all territories.

At nests on the Olympic Peninsula, grebes, scoters, cormorants, and murres were the principle bird prey (Table 1). Rockfish and Ling-cod made up 87% of all fish remains and were each found at almost one-third of all territories. Mammals and invertebrates together were much less important, comprising only 7% of the total food items.

Grebes, murres, and scoters were the most common bird prey items at nests along Puget

Sound. Rockfish and Starry Flounder were the principle fish prey items, while mammals and invertebrates were poorly represented.

Our findings agree with the generalization that coastal nesting Bald Eagles feed more on birds than on other taxa, and that nests located in other than coastal areas show a higher proportion of fish remains (Chrest 1964; Retfalvi 1970; DeGrange and Nelson 1982; *references in* Todd et al. 1982; Cash et al. 1985; *but see* Grubb and Hensel 1978). Seabirds made up a majority of the bird species found in prey remains and Bald Eagles use a variety of methods to capture them, including team-hunting, excavating nesting burrows, surprise, and pirating (*references in* Todd et al. 1982; DeGrange and Nelson 1982; Angell and Balcomb 1982).

Our fish collections contained few vertebrae but a large number of skulls. This suggests eagles fed on fish heads discarded by fishermen, a behavior that has been reported elsewhere (Dunstan and Harper 1975; Todd et al. 1982; Cash et al. 1985). Alternatively, fish skulls may have appeared in the collections more often because they were less digestible and persisted longer than vertebrae. However, many of the fish species were bottom-dwelling species which would not normally be available to eagles. We suggest that these fish were discarded by sport or commercial fisherman who consider some species of bottom fish undesirable.

Retfalvi (1970) found that Old World Rabbits were a common food item at two nests he studied on San Juan Island. He suggested that eagles scavenged rabbits killed by cars or farm machinery. Platt (1976) observed that wintering Bald Eagles in a Utah desert subsisted on Black-tailed Jackrabbits (*Lepus californicus*) killed by hunters or automobiles.

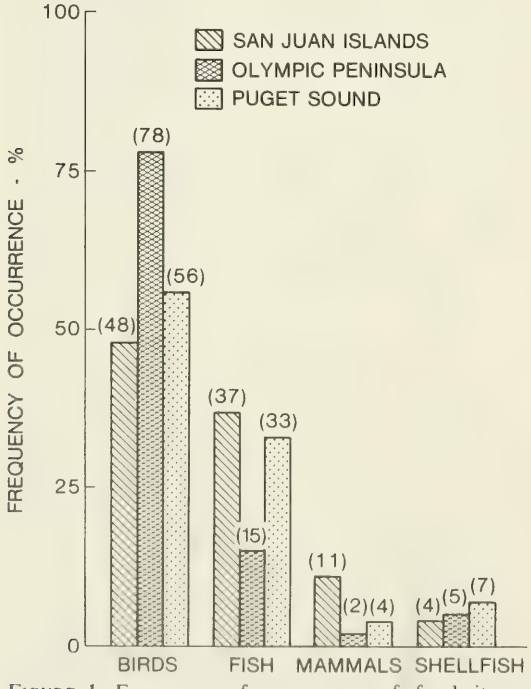

FIGURE 1. Frequency of occurrence of food items collected below nests and at perch trees of Bald Eagles in the San Juan Islands, Olympic Peninsula and Puget Sound in western Washington, 1980-1981. Numbers in parentheses are the percentages of each taxa that occur in each area.

Analysis of methodology

We observed the delivery of 47 items during 247 hours of observations (0.19 items/hour). Diets determined from observation of food deliveries contrasted sharply with food debris found beneath nests ($\chi^2 = 397.23$, df = 1, $P < 0.001$). One Old World Rabbit was found in collections while no mammals were seen in direct observations. Birds were heavily represented in collections (55%) but were seldom observed being brought to nests (8%), while fish were commonly seen being brought to nests (92%), but were less prevalent in collections (44%).

Our observations suggest that food collections taken from the base of eagle nests do not accurately reflect prey brought to nests. Retfalvi (1965: 138) compared food information from direct observation with collections underneath one nest on San Juan Island and found that birds were under-represented in observations. Todd et al. (1982) documented a similar bias between observations and collections at nests in coastal Maine. Our results suggest a more accurate assessment of food habits is possible when nest observations are supplemented with food debris collections (Collopy 1983).

Chemical contamination

Glaucous-winged Gulls had detectable levels of DDE in liver ($\bar{x} \pm SD$ ppm: wet weight - 0.63 ± 0.48, n = 9; lipid weight - 13.54 ± 8.23, n = 9) and breast tissue samples (wet weight - 0.72 ± 0.24, n = 5; lipid weight - 20.4 ± 3.13, n = 5). PCBs were found in gull liver (wet weight - 1.54 ± 1.05, n = 9; lipid weight - 30.49 ± 22.60) and breast tissue (wet weight - 1.86 ± 0.61, n = 5; lipid weight - 52.4 ± 6.84). Tissues from three of the four rabbits contained neither DDE or PCBs, while one rabbit had a detectable level of DDE (lipid weight - 0.20 ppm).

These levels of DDE and PCBs are within the range found in prey items of Bald Eagles in Maine and in White-tailed Eagles (*Haliaeetus albicilla*) in Finland and within the values known to suppress eagle productivity (Koivusaari et al. 1976; Wiemeyer et al. 1978; Grier 1982; Wiemeyer et al. 1984). Bald Eagles in our study area contain DDE and PCBs (Kaiser et al. 1980; Angell and Balcomb

1982; Reichel et al. 1984; Washington Department of Wildlife, unpublished data), and our results indicate a potential source of this contamination.

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Summer and Fall Activity Patterns of Cottontail Rabbits, *Sylvilagus floridanus*, in Southern Illinois

DWAYNE A. W. LEPITZKI[1]

Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale, Carbondale, Illinois 62901
[1]Present address: Institute of Parasitology, McGill University, Macdonald College, 21,111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0

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Nine eastern cottontail rabbits (*Sylvilagus floridanus*) confined in a 1.46 ha outdoor enclosure in southern Illinois and collared with activity sensing radio-transmitters were monitored July to November 1984 to determine activity patterns. A total of 9660 4-minute scans from continuous 24-hour monitoring indicated high or low relative activity. The daily activity pattern was unimodal with most activity occurring at night. Activity was greater when temperatures were cooler than when warmer and was not related to precipitation. An hypothesis of an August-September activity time transition and a similar one for spring is presented to explain the conflicting reports of the relationship between onset and cessation of activity and sunset and sunrise.

Key Words: Cottontail Rabbit, *Sylvilagus floridanus*, activity, radio-telemetry, southern Illinois.

An understanding of daily activity patterns and mechanisms controlling these patterns is basic to biological knowledge of animals. Daily and seasonal activity patterns of eastern Cottontail Rabbits have been studied with the aid of automatic radio-tracking systems (Mech et al. 1966), micro-treadle switch equipped outdoor cages (Lord 1964), and through observational techniques (Holler and Marsden 1970). The most common technique used to indirectly address cottontail activity has been roadside automobile censuses (Fafarman and Whyte 1979; Kline 1965; Lord 1959, 1961; Newman 1959; Wight 1959).

Investigations of the influence of temperature, rainfall, and sunrise and sunset on cottontail activity have produced conflicting results (Fafarman and Baker 1979; Fafarman and Whyte 1979; Holler and Marsden 1970; Kline 1965; Lord 1959, 1961, 1964; Mech et al. 1966; Newman 1959; Wight 1959). An apparent transition in daily bimodal activity curves (Lord 1964) from higher morning peaks during summer (May to July) to higher evening peaks in winter (September to April) has also been reported (Lord 1959). Activity monitoring radio-transmitters were attached to cottontails to re-examine the August transition and the influence of temperature, precipitation, and sunrise and sunset in a semi-captive setting.

Study Area

Animals were kept in a 1.46 ha enclosure in southern Illinois (37° 41′N, 89° 15′W). The enclosure was rabbit and ground-predator proofed using mesh chain link fences buried in the ground (Yaich 1981). Habitat was primarily old field dominated by various grasses (*Dactylis glomerata, Festuca* spp., *Tridens flavus,* and *Agrostis alba,* among others); blackberry bushes (*Rubus allegheniensis*) provided cover. Five feeders supplied a pelleted food ration ad libitum to a population estimated at 51 at the initiation of this investigation. Rabbits were periodically collected (Lepitzki 1986), resulting in an estimated population of 14 at the conclusion of studies.

Methods

Nine cottontails were neck collared with activity monitoring transmitters (Advanced Telemetry Systems, Bethel, Minnesota); collar weight did not exceed 4.9% of the rabbit's body weight. An omni-directional antenna (RA-6B, Telonics Inc., Mesa, Arizona) atop a 10 m metal pole located near the center of the pen, a scanning receiver (ATS), digital data processor (TDP-2, Telonics), and a dual chart recorder (TDR-1, Telonics) gathered, processed, and recorded period and amplitude of transmitted signals. Power was supplied by a portable battery pack interchanged with a 12 volt marine battery which allowed continuous 24-hour activity monitoring.

Each rabbit was monitored for 4 minutes. Radio frequencies not transmitted by any of the collars were used to separate rabbit collar frequencies in the scanning sequence so that individual rabbits could be identified on the resulting chart. As collared animals were removed from the pen for concurrent disease investigations (Lepitzki 1986) [151.177 removed 1 October; 151.166 and 151.206 removed 16 October; 151.218 removed 21 October; 151.185 and 151.237 removed 22 October; 151.160, 151.227, and 151.247 removed 4 November] their radio frequencies and corresponding blank

frequencies were removed from the scanning sequence. Activity monitoring was suspended during rabbit collections.

An arbitrary assessment of relative activity was made for each 4-minute scan. If the period changed 3 times or less during the scan, the animal was considered to have low activity; if the period changed more than 3 times, the animal was considered to have high activity. Signal amplitudes were associated with period changes; the larger the number of period changes, the greater the size and number of amplitude deflections. Each scan was then assigned to the 15-minute time block (Central Daylight Time) in which it occurred. The frequency procedure of the Statistical Analysis System (Helwig and Council 1979) quantified the number of low activity and high activity scans per half-hour per rabbit.

The apparent August transition and the influence of temperature and precipitation were investigated by separately sorting the data set on the basis of calendar dates and daily temperature and precipitation levels; the latter two criteria were obtained from the Carbondale Recording Station 6.5 km distant (National Oceanic and Atmospheric Administration). To control for the possibility of individual rabbit variability, total, pooled, and heterogeneity G-tests (Sokal and Rohlf 1981) were used (RXC procedure of BIOM, Rohlf 1983) with a probability level of $P < 0.05$. A significant heterogeneity G-test suggests that not all the rabbits behaved in the same manner.

Due to the nature of the data, the influence of sunrise and sunset on relative activity was crudely investigated by sorting the data set into early and late sunrise and sunset seasons. Each season corresponded to a block of time when sunrise or sunset varied within a half-hour period. Total, pooled, and heterogeneity G-tests were then performed on amounts of relative activity for the hour before and the hour after each sunrise and sunset period within each season.

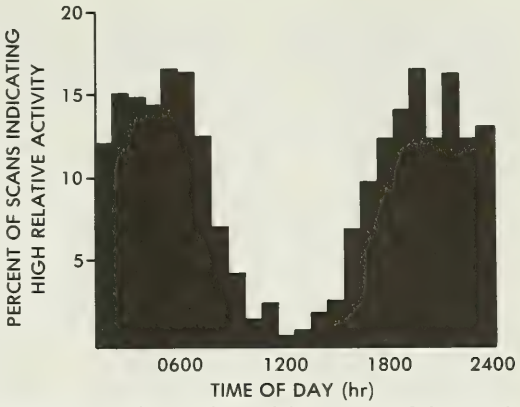

FIGURE 1. Daily relative activity pattern of Cottontail Rabbits in southern Illinois, July to November, 1984. This is a composite of 9660 4-minute scans from nine rabbits.

Results

The nine rabbits exhibited an apparent bimodal daily activity pattern (Figure 1). Because no significant differences were detected in the hourly activity levels during the morning (0100 to 0759 h) ($G = 5.883$, $df = 6$, $P > 0.05$) or the evening (1700

TABLE 1. Relative activity of nine Cottontail Rabbits in southern Illinois under varying levels of season, temperature, and precipitation, July to November, 1984.

	Morning[a]			Evening[b]			Daily total[c]		
	high[d]	low[e]	%[f]	high	low	%	high	low	%
Season									
8 July to 16 August	57	360	13.7	69	475	12.7	138	1246	10.0
17 August to 25 September	203	1105	15.5	228	1362	14.3	481	3973	10.8
26 September to 4 November	156	980	13.7	159	1149	12.1	360	3462	9.4
Daily maximum temperature									
< 20°C	88	382	18.7	82	443	15.6	190	1304	12.7
20°-29°C	231	1356	14.6	250	1599	13.5	541	4788	10.2
> 29°C	97	707	12.1	124	944	11.6	248	2589	8.7
Daily precipitation									
0 cm	269	1601	14.4	329	2089	13.6	666	5872	10.2
< 1 cm	62	366	14.5	46	310	12.9	124	1092	10.2
1-2 cm	55	318	14.8	46	348	11.7	117	1117	9.5
> 2 cm	30	160	15.8	35	239	12.8	72	600	10.7

[a]0100-0759 h; [b]1700-2459 h; [c]0100-2459 h; [d]number of scans indicating high relative activity; [e]number of scans indicating low relative activity; [f]percent of scans indicating high relative activity.

TABLE 2. Relative activity of cottontails in southern Illinois before, during, and after sunrise and sunset for early and late sunrise and sunset seasons. During the early sunrise season (30 July to 5 September) and late sunrise season (6 September to 11 October) sunrise occurred between 0600 to 0630 hours and 0630 to 0700 h, respectively. During the early sunset season (5 August to 29 August) and late sunset season (18 September to 8 October) sunset occurred between 1930 to 2000 h and 1830 to 1900 h, respectively.

Sunrise Season								Sunset Season							
30 July to 5 September				6 September to 11 October				5 August to 29 August				18 September to 8 October			
time of day (h)	high[a]	low[b]	%[c]	time of day (h)	high	low	%	time of day (h)	high	low	%	time of day (h)	high	low	%
0500-0600	24	132	15.4	0530-0630	28	151	15.6	1830-1930	7	55	11.3	1730-1830	11	117	8.6
0600-0630	14	81	14.7	0630-0700	9	79	10.2	1930-2000	2	25	7.4	1830-1900	6	63	8.7
0630-0730	26	128	16.9	0700-0800	18	157	10.3	2000-2100	1	54	1.8	1900-2000	22	121	15.4

[a]number of scans indicating high relative activity; [b]number of scans indicating low relative activity; [c]percent of scans indicating high relative activity.

to 2459 h) ($G = 12.816$, $df = 7$, $P > 0.05$), all subsequent data analyses were carried out on the pooled morning, evening, and daily total activity levels.

The group of nine rabbits were less active during mid-day (0800 to 1659 h) than during either the morning ($G = 270$, $df = 1$, $P < 0.05$) or evening ($G = 243$, $df = 1$, $P < 0.05$). Morning and evening activity levels did not differ ($G = 2.184$, $df = 1$, $P > 0.05$), therefore the apparent bimodal nature of the daily activity pattern was not statistically reinforced.

The rabbits, as a group, did not differ ($P > 0.05$) in their morning, evening, and daily activity levels between the early (8 July to 16 August) and late (26 September to 4 November) seasons (Table 1). However, total and heterogeneity G-tests for morning, evening, and daily activity levels were different ($P < 0.05$) for most seasonal comparisons. Thus, the rabbits were responding to season in some manner as indicated by G-tests but the exact nature of this response was obscure.

Rabbits seemed to be more active when the weather was cool (Table 1). Differences ($P < 0.05$) in morning and daily activity levels were detected in all temperature comparisons. In addition, rabbits were significantly more active ($P < 0.05$) in the evening when it was cool (daily maximum temperature $< 20°$ C) than when it was hot (daily maximum temperature $> 29°$C). Non-significant ($P > 0.05$) heterogeneity G-tests indicated all rabbits behaved similarly.

No trends were apparent in cottontail activity under the four levels of precipitation examined (Table 1). Because no significant ($P > 0.05$) differences in relative activity were seen between any of the precipitation levels in which rain accumulated, a rain versus no rain comparison was examined. Significant heterogeneity G-tests indicated not all the rabbits behaved similarly when it rained; therefore, the biological importance of a significant total G-test was uninterpretable.

The rabbits, as a group, appeared to be more active following sunrise and more active before sunset in the early sunrise and sunset seasons, respectively (Table 2), while they appeared to be less active following sunrise and more active following sunset during the late sunrise and sunset seasons (Table 2). However, the only significant difference in activity prior to and after sunrise or sunset occurred in the early sunset season; the rabbits were significantly more ($P < 0.05$) active before sunset in the early sunset season. Although not all rabbits behaved similarly in their response to sunrise during the early sunrise season (heterogeneity G-test, $P < 0.05$), a non-significant ($P > 0.05$) heterogeneity G-test indicated all

rabbits behaved similarly during the early sunset season and during the late sunrise and sunset seasons.

Discussion

Annual and daily cycles of rabbit activity have been primarily investigated using roadside automobile censuses (Fafarman and Whyte 1979; Kline 1965; Lord 1959, 1961; Newman 1959; Wight 1959). Inherent in this technique are problems related to consistency and experience of observers, and visibility and population levels of rabbits. For instance, low population levels of rabbits would make it difficult to assess daily and annual activity levels.

Only Lord (1964) and Mech et al. (1966) have used electronic techniques to directly assess cottontail activity. Lord (1964) studied animals housed in small outdoor cages with a constant food supply nearby; both factors may have subtly affected results. Mech et al.'s (1966) study only extended for the first three months of the year and results were based on four wild, unconfined cottontails. These latter researchers were concerned about variable daily activity cycles within and between individuals and cautioned "pooling data from several individuals and many days is likely to bias conclusions and even to obscure possible relationships " (Mech et al. 1966: 411). Heterogeneity G-tests are a potential method to examine individual variability. In addition, even though individuals may show variation, a general overall species trend may be apparent.

The rabbits did not exhibit a bimodal daily activity curve similar to that suggested but not statistically tested for by Lord (1961, 1964). Although three definite regions corresponding to morning, mid-day, and evening could be superimposed on the daily activity pattern I noted, morning and evening activity levels were not statistically different. As a result, I did not find, nor should I have expected to find, the August transition from higher morning peaks during summer to higher evening peaks during winter found by Lord (1959). Furthermore, although not stated, Lord's (1961, 1964) data also indicated no transition exists.

Based on automobile censuses, morning peaks of activity are generally higher than evening peaks throughout the year (Lord 1961; Newman 1959); however, Lord (1964) reported higher morning peaks in only June, July, October, and December, using rabbits in outdoor cages. I consistently found that morning peaks were always slightly but not statistically higher than evening peaks of activity (Table 1). This would suggest that automobile censuses can be conducted at any time during the night.

A tendency for activity in summer to begin later, slower, and continue later in the morning (Lord 1961) and to have increased duration (Lord 1964) may be related to temperature. My data support a preliminary report by Wight (1959) that high temperatures materially reduced number of rabbits observed during automobile censuses in July in Missouri. Although no correlations were noted between rabbit numbers and maximum and minimum temperatures 12-hours prior to automobile censuses in the morning throughout the year in east-central Iowa, a positive correlation between rabbit numbers and the overnight temperature decline during June and July was found (Kline 1965). However, rabbit numbers determined by nighttime automobile censuses were not significantly related to temperature during November and December in southern Texas (Fafarman and Baker 1979; Fafarman and Whyte 1979) or during January to March automobile censuses in south-central Iowa (Newman 1959). No doubt geography, seasonal temperature variations, and yearly temperature regimes influence animal activity. In southern Illinois, rabbits seem to be more active when it is cooler during late summer and fall.

I did not find any general trends linking precipitation and rabbit activity although not all rabbits behaved in a similar manner. Kline (1965) also reported no relationship between number of rabbits seen on automobile censuses throughout the year and amount of precipitation during the previous night. Others, however, have noted both negative and positive correlations (Fafarman and Baker 1979; Fafarman and Whyte 1979; Newman 1959). The latter three studies relied on data collected during November through March, a period I did not examine. In southern Illinois, rain does not seem to increase or decrease relative activity of cottontails during late summer and fall. In east-central Illinois, Lord (1959, 1961) may have either suspected a derogatory effect or logistics prevented censuses during precipitation because he aborted censuses if rain was encountered.

The actual roles of sunrise and sunset and cessation and onset of cottontail activity are disputed. It is also very difficult to compare studies which have been done at differing latitudes and times of the year. Mech et al. (1966) noted a relationship between onset of activity and sunset and cessation of activity and sunrise during January to March in Minnesota; a time of the year when sunrise and sunset times are rapidly changing. Newman (1959) made a similar observation using roadside automobile censuses during the same time of the year in Iowa. However, Lord (1961, 1964) concluded that some factor other than sunset stimulated increased activity.

Furthermore, onset of activity occurred between 1600 hours (Central Standard Time) (Lord 1964) and 1700 hours (CST) (Lord 1961) throughout the entire year. Similarly, sunrise did not result in cessation of activity (Lord 1964); all activity terminated between 0700 hours (CST) (Lord 1961) and 0900 hours (CST) (Lord 1964) regardless of the season. Studies by Kline (1965) on sunrise and Holler and Marsden (1970) on sunset, and this study may help to resolve the dilemma.

Kline (1965) noted fewer rabbits after sunrise in automobile censuses from November to March, similar to Mech et al.'s (1966) suggestion, while more rabbits were seen after sunrise in June and July, similar to my data on sunrise. The trends shown in activity for both my early (30 July to 5 September) and late sunrise (6 September to 11 October) seasons may indicate that in August, rabbits are more active after sunrise while in September, rabbits are more active before sunrise. This suggests that a transition from more activity after sunrise to more activity before sunrise occurs in late August — early September; a conclusion similar to the annual activity pattern noted by Kline (1965).

I further hypothesize that the late August — early September transition also occurs with sunset. I found significantly more activity before sunset in the early sunset season (5 August to 29 August). In addition, my data indicated a possible trend towards more activity after sunset in the late sunset season (18 September to 8 October). These two observations concur with the conclusion of Holler and Marsden (1970) who noted that during late spring and summer, onset of activity was well before sunset while in late winter and early spring, onset occurred during the twilight period following sunset. This latter observation agrees with an association between onset of activity and sunset reported by Mech et al. (1966). In addition, in order for an August-September transition to occur, there must also be a similar transition in late spring.

Unfortunately, most of my hypothesis is based on trends and not statistical evidence. Statistically significant correlations between sunrise and cessation of activity and sunset and onset of activity may occur only when sunrise and sunset times are rapidly changing as in the study by Mech et al. (1966). My data may have been too crude and my sample size too small to show significant correlations. Regardless, cottontails are more active at night and less active during the day. The onset of this nightly activity must therefore be associated with the onset of night and the cessation of the activity must therefore be associated with the onset of day. The exact timing and nature of these correlations and their underlying biological meaning, if any, remain to be investigated.

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The Importance of Individual Territories to the Long-Term Production of Common Loons, *Gavia immer*, in Northwestern Ontario

PETER ROSS CROSKERY

R.R. 1, 50 Ridge Road, Grimsby, Ontario L3M 4E7

Croskery, Peter Ross. 1990. The importance of individual territories to the long-term production of Common Loons, *Gavia immer*, in northwestern Ontario. Canadian Field-Naturalist 104(4): 557–560.

Reproductive success of Common Loons was monitored on 21 multiple territory lakes in northwestern Ontario. A total of 254 territories were surveyed in each of four consecutive years. Production by territorial pairs was consistent in all four years and averaged 0.32 young. Total young fledged from the study lakes ranged from 73 to 85. In nearly half of all territories, no young were produced and in approximately 20% of the territories young were produced in one of four years. In only 76 territories were young seen in more than one of four years and these territories accounted for 188 successful breedings, almost 80% of all young produced.

Key Words: Common Loon, *Gavia immer*, territory, Ontario, reproduction, territorial reuse, breeding success.

Wilderness areas of North America are the preferred habitat of Common Loons (*Gavia immer*) (Vermeer 1973a). As these areas have been lost to increased human activity, Common Loon populations have suffered major declines (Smith et al 1973; Vermeer 1973b; Ream 1976; Sutcliffe 1978; Titus and VanDruff 1981). With declining populations (Cross 1979; McIntyre 1979; Metcalf 1979; Sawyer 1979; Sutcliffe 1980), concern over the reduction of the species from traditionally populated areas has arisen.

The recent focus of much research on Common Loons has been the species' reproductive success. Researchers have examined loon populations in specific areas to determine whether the species can maintain a stable population. This research has not included an assessment of the reproductive performance of individual breeding pairs nor how individual territories may affect the overall stability of an area's Common Loon population.

In this study I investigated the reproductive biology of the Common Loon in an area free from the impacts of human recreational activity. Specifically, I examined the importance of individual territories to the production of Common Loons.

Methods

A total of 55 lakes in a sparsely populated area of Canada located near Ignace Ontario (Lat. 49 25'N; Long. 91 40'W), were surveyed during a four-year period. Only 21 lakes that supported multiple loon territories and four consecutive years (1983-86) of productivity data are reported (Table 1). Lake size ranged from the largest, Mameigwess (5314 ha) to the smallest, Snowstorm (69 ha). Not all small lakes included in the study area supported loons and those that did show some loon use were not consistently occupied each year. On several small lakes, pairs raised young in one year but no nesting attempt was undertaken on the lake in subsequent years. On other small lakes no nesting attempt was found although birds were resident in all four years while on other lakes loons were only occasional visitors. Because of these irregularities of use, small single territory lakes were excluded from this analysis. (Total annual young from all single territory lakes within the study area was less than 5% of that produced within the study area.)

Lakes were surveyed by boat, at approximately 10 days intervals throughout each of the summer breeding seasons. Bird sightings were mapped according to location, time of day and aggregate composition (i.e. single, pair, pair with young). Territories were geographically identified on the basis of behavioural observations, nest locations, and observed young. Active terrritories were defined as those areas occupied by at least one bird in 75% of the searches conducted prior to 1 August in each year. A territory was considered to be "successful" if at least one young survived to eight weeks of age.

Results

The 21 lakes contained 254 loon territories which were occupied in each of the four years of this study. Lake shoreline showed a stronger correlation with number of territories ($r = 0.9582$; $n = 254$) than did lake size ($r = 0.9034$; $n = 21$). The number of territories in which young annually fledged was remarkably consistent and varied between 57 and 67 (22-26%). Slightly more variation occurred in the actual number of young fledged (73-85), since some pairs fledged two instead of one young.

TABLE 1. Common Loon (*Gavia immer*) young production by lake, year and territorial reuse, Ignace, Ontario, Canada, 1983-1986.

Lake	Territories	Area (ha)	Shore (km)	$\bar{X}$ depth	Territories fledged YOY (YOY fledged) 1983	1984	1985	1986	Number Times Territory Used 0	1	2	3	4
Press	42	3621	118.7	5.6	7(8)	15(17)	10(12)	6(9)	20	12	5	4	1
Mameigwess	33	5314	76.7	16.1	3(4)	3(4)	4(6)	5(7)	23	6	3	1	0
Paguchi	26	2449	69.8	9.1	10(10)	10(11)	5(7)	8(11)	11	3	6	6	0
Indian	23	3966	87.7	9.4	4(4)	3(3)	2(3)	3(3)	14	6	3	0	0
Raleigh	23	1699	50.2	10.4	4(6)	6(7)	9(14)	7(10)	9	7	4	1	2
Flatrock	16	1358	37.5	9.4	3(4)	2(3)	4(5)	3(5)	9	3	3	1	0
Arethusa	11	783	37.8	5.4	5(6)	6(9)	5(7)	4(6)	2	2	4	2	1
Victoria	0	938	33.0	9.5	2(2)	2(2)	1(2)	1(2)	5	4	1	0	0
Healthwalt	10	743	20.3	4.8	3(6)	2(4)	1(2)	1(2)	7	0	1	2	0
Sandbar	9	1292	23.0	6.0	0	0	1(2)	1(2)	8	0	1	0	0
Agimac	9	1223	35.6	3.2	2(3)	0	4(5)	4(5)	4	1	3	1	0
Watcomb	8	1055	23.0	7.0	2(3)	4(5)	1(1)	2(3)	2	3	3	0	0
Encamp	6	458	22.4	3.2	1(2)	2(3)	1(1)	2(2)	2	2	2	0	0
Raven	6	389	11.4	2.7	1(2)	3(4)	1(2)	2(2)	3	1	1	1	0
Cloven	4	338	23.3	6.5	0	1(1)	0	0	3	1	0	0	0
Pike	4	132	9.4	3.7	1(1)	3(3)	3(5)	3(6)	0	0	2	1	1
Snowstorm	4	69	7.2	8.4	3(4)	2(3)	3(4)	2(3)	0	1	1	1	1
Square	4	256	11.9	6.6	3(4)	0	2(2)	2(3)	0	2	1	1	0
Cecil SW #2	2	72	6.8	2.6	2(3)	2(3)	1(2)	1(1)	0	0	0	2	0
Moss	2	120	6.3	1.6	1(1)	1(1)	1(1)	1(1)	0	0	2	0	0
Godden	2	161	7.2	4.0	0	0	1(2)	0	1	1	0	0	0
	254				57(73)	67(83)	60(85)	58(83)	123	55	46	24	6

Although all 21 lakes produced some young within the four year period, 48.8% of 254 territories failed to fledge any while 51.2% of the territories produced young at some point during the study period. Of the ones with young, 55 (41.9%) territories produced young in only 1 of 4 years, 46 (35.1%) in 2 of 4 years, 24 (18.3%) in 3 of 4 years and 6 (4.5%) in each of the 4 years.

The total number of successful breeding attempts for all four years was 242. Of this total, 54 (22.3%) successful breedings occurred in territories where the adults produced young in only one of four years. Almost 80% (n = 188) of all successful breedings during 1983-1986 came from 76 territories that produced young in more than one breeding season.

Discussion

The results indicate that productivity of the Common Loon is lower in northwestern Ontario than reported elsewhere in North America. The number of young fledged per territorial pair was 0.29 (1983), 0.33 (1984), 0.33 (1985) and 0.33 (1986). Only McIntyre's (1978) study area in north central Minnesota's Itasca State Park showed similar productivity (0.27-0.31) while elsewhere in Minnesota, reported loon productivity has been 0.50 (Olson and Marshall 1952) and 0.42-0.54 (Titus and VanDruff 1981). Other North American loon research has reported loon productivity near 0.50 and includes north central Saskatchewan (Yonge 1981), New Hampshire (Sutcliffe 1980), Maine (Sawyer 1979), Vermont (Metcalf 1979), Alberta (Vermeer 1973b). An exception was New York state where productivity of Common Loons was the highest (0.83-0.84) so far reported in North America (Trivelpiece et al. 1979).

Several researchers have speculated that a loon production rate of 0.50 young fledged per territorial pair is required to ensure a healthy, stable population (Eriksson 1986; Sutcliffe 1980). However, the northwestern Ontario data does not support this conclusion since productivity for loons in northwestern Ontario was quite a bit lower than this value and there was no evidence of a declining Common Loon population.

Although loon productivity ($\bar{X} = 0.32$) for northwestern Ontario was substantially lower than in most other studies, the total number of young produced was higher than that reported elsewhere. This is a result of the vast number of lakes providing suitable habitat, minimal human disturbance, and high number of resident territorial pairs. Therefore, from a productivity standpoint (i.e. young fledged per territorial pair) northwestern Ontario is lower than most other North American locations; however, on an absolute production basis (total young produced), northwestern Ontario ranks high in North America.

Although a large loon population occurs in northwestern Ontario, densities of adult birds are ranked intermediate when compared to reported densities from other North American locations. Northwestern Ontario had a Common Loon density of 1 adult bird per 52 ha (0.019 adults/ha) of lake surface. New Hampshire had the least dense loon concentration at 210 ha/loon (0.005 adults/ha) while north central Minnesota (McIntyre 1978) and north central Saskatchewan (Yonge 1981) had the densest loon populations at approximately 19.5 ha per adult loon (0.051 adults/ha).

It should be noted that this comparison of loon densities does not represent the total loon density of northwestern Ontario since it involves only actively territorial birds. Within northwestern Ontario there is a large non-territorial component to the area's Common Loon population (Croskery 1988a). Since these birds do not maintain territories, they were not included in the area's breeding population estimate. If these birds were included in density calculations, the loon population of northwestern Ontario would approach the high density values reported for north central Minnesota and Saskatchewan. Neither Yonge (1981) nor McIntyre (1978) make mention of non-territorial flocks and therefore it is presumed that they did not occur in their study areas.

Although northwestern Ontario includes a large number of loon territories, almost half never produced young. Approximately 20% of all monitored territories produced young only once every four years, contributing 22.6% to the total long term loon production of the area. Less than 30% of all territories contributed 77.4% of all loon production over the long term. These were the territories that showed a regular repeated annual production of young. From a wildlife management standpoint, should these major loon producing territories be subjected to recreational development, the impact upon northwestern Ontario's Common Loon population could be significant.

Larger lakes with the highest number of territorial pairs had the highest production of young. However, these larger lakes also had the highest number of non-contributing territories. Lakes with four or less territorial pairs had some production from each territory although the regularity of production by individual territory was no different for these lakes than for the larger lakes. No lake within the study area showed a uniquely high reuse and breeding success of all its territories.

Although it has been argued that experience accounts for the success of some breeders (Welty

1982), Croskery (1988b) demonstrated that young loons will be produced in high quality habitat within two years of reoccupation by a new pair. Furthermore, it seems doubtful that 70% of all territories included in this study would be occupied by inexperienced breeders in each of four consecutive years.

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Habitat Use and Selection by Male Sharp-tailed Grouse, *Tympanuchus phasianellus campestris*

MICHAEL W. GRATSON[1], JOHN E. TOEPFER[2], and RAYMOND K. ANDERSON

College of Natural Resources, University of Wisconsin, Stevens Point, Wisconsin 54481
[1]Present address: Environmental Modeling and Assessment, Environmental Sciences and Technology, EG&G Idaho, Inc., MS 2110, Idaho Falls, Idaho 83415
[2]Present address: Fort Totten College, Fort Totten, North Dakota 58335

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We identified vegetation types that were heavily used (used $\geq$ 20% of the time) and that were selected (percentage use $>$ percentage availability) by male Prairie Sharp-tailed Grouse (*Tympanuchus phasianellus campestris*) using 26 radio-tagged birds on three study areas in northwestern Wisconsin. Vegetation types that were heavily used included grass-shrub, shrub-grass, shrub, open conifer woods, sedge meadow, shrub marsh, and cropland, depending upon the season. We show that habitat selection occurred at the level of the seasonal home range during the summer (i.e., males selected summer home ranges with higher percentages of shrub-grass and cropland, and lower percentages of deciduous woods, sedge meadows, and open water than available on the study areas). However, within summer monthly home ranges, vegetation types were used by males in proportion to their availability, indicating no selection. Within monthly home ranges at other times of the year, males selected grass-shrub (fall months), deciduous woods (winter months), open coniferous woods (winter months), shrub marsh (spring months) and cropland (spring, fall, winter months). We suggest that both habitat use and selection statistics are important in determining the relative importance of particular vegetation types.

Key Words: Sharp-tailed Grouse, *Tympanuchus phasianellus campestris*, habitat selection, radio-tagging, Wisconsin.

Sharp-tailed Grouse, *Tympanuchus phasianellus*, formerly occurred in at least six Canadian provinces, two territories, and 21 states in North America (Aldrich 1963), but they are now restricted to six provinces, two territories, and 13 states (Miller and Graul 1980). In north-central United States and south-central Canada the Prairie Sharp-tailed Grouse (*T. p. campestris*) occupies $<$ 10% of its former range in Michigan and Wisconsin, $<$ 30% in Minnesota, and 50-90% in Manitoba and Saskatchewan (Miller and Graul 1980). Previous reports of habitat use are unsystematic and often casual (Grange 1948; Hamerstrom and Hamerstrom 1951; Ammann 1957), and there are no studies reporting on the detailed patterns of habitat selection year-round by the prairie subspecies. Details of habitat use by *T. p. jamesi*, the plains subspecies, have been described (Moyles 1981; Swenson 1985). Our study identifies heavily-used and selected habitat components (vegetation types) throughout the year by male Prairie Sharp-tailed Grouse at three study areas in northwestern Wisconsin. A summary of habitat selection by females was reported in Gratson (1988).

Study Areas and Methods

Our three study areas varied in size, habitat composition, and grouse population densities during 1977-79. Douglas County (DC), the Namekagon Barrens (NB), and Crex Meadows (CM) were within Wisconsin's 3900 km^2 Northwestern Pine Barrens (46°N, 92°W), a glacial outwash plain of sandy soils over pre-cambrian sandstone. DC (1522 ha; T44N, R12W), 5 km southwest of Solon Springs, is an oak (*Quercus* spp.) — aspen (*Populus* spp.) — pine (*Pinus* spp.) savanna (Hamerstrom 1963; Gratson 1988), and is surrounded by wooded uplands and open and wooded wetlands. The density of advertising males on leks increased from approximately 0.84/km^2 to 1.12/km^2 during the three years. NB (1849 ha: T42N, R12W), 22 km southwest of DC and 19 km west of Minong, is a large block of relatively homogenous shrub-prairie surrounded by wooded uplands and lowlands (Gratson 1988). Male densities averaged 0.51/km^2 for the three study years and were stable. CM (12 185 ha: T39N, R18W) is a heterogenous block of wetlands interspersed with shrub-prairie and wooded uplands that is surrounded by small dairy and grain farms, upland woods, and river-bottom lowlands. It lies 2 km north of Grantsburg and 45 km southwest of NB. Male density rose from 0.33/km^2 to 0.46/km^2. A newly reintroduced population of Prairie Chickens (*Tympanuchus cupido*) was also present; the number of males on booming grounds during each year ranged from 16-25.

Species composition of native vegetation types has been described (Hamerstrom 1963; Vogl 1964;

Beck and Vogl 1972; Gratson 1983, 1988). The shrubs dominating the grass-shrub, shrub-grass, and shrub vegetation types on these study areas included oaks (*Quercus ellipsoidalis, Q. macrocarpa*), willow (*Salix discolor, S.humilis), Hazel (Corylus americana*), Sweet Fern (*Comptonia perigrina*), rose (*Rosa* spp.) and less commonly, very young pine (*P. banksiana*) and aspen (*P. tremuloides, P. grandidentata*). The cropland vegetation type consisted of mixtures of buckwheat, corn, and rye at CM, buckwheat at NB, and clover at DC.

Twenty-six males, captured at various times of year, were radio-tagged with a back-mounted radio package (Dumke and Pils 1973) and radio-located 1-3 times per day using a vehicle-mounted 8-element antenna. Estimated maximum location error was $\pm$ 33 m (3421 m^2) (n = 46 trials) for stationary transmitters. We used a rotational sampling schedule of $\geq$ 3-4 sample periods (each period = 3-7 consecutive days) per month per study area. Frequently, birds at 2-3 study areas were sampled (radio-located) during the same periods.

We wished to estimate both vegetation type use and vegetation type selection by males because both may be helpful in establishing the overall "importance" of particular vegetation types to the survival and reproductive success of males. Use and selection were defined for coarse-grained and fine-grained analyses.

On a fine-grained scale, vegetation type use was defined as the percentage of the total radio-locations of males that were located in a particular vegetation type during a monthly time period. On a coarse-grained scale, vegetation type use was defined as the percentage of an average seasonal home range (spring, summer, fall, winter) that a particular vegetation type contributed. Vegetation type use was a quantitative estimate (a percentage).

On a fine-grained scale, vegetation type selection was defined as the nonrandom use of a particular vegetation type within monthly home ranges. As used here, random use was defined as an insignificant difference between the average percentage of time males were radio-located in a particular vegetation type and the average percentage that a particular vegetation type contributed to an average home range. On a coarse-grained scale, vegetation type selection was defined as the nonrandom percentage that a particular vegetation type contributed to an average seasonal home range. As used here, random use was defined as an insignificant difference between the percentage contribution of a particular vegetation type to an average seasonal home range and the percentage contribution of the vegetation type to the composition of a study area. Vegetation type selection was a qualitative variable (use significantly greater than that expected, or use significantly less than that expected).

Vegetation type use and selection on a coarse-grained scale as defined above should reflect the results of "decision-making" by males on where their seasonal home ranges should be located for success at reproductive and survival, within large blocks of habitat (study areas). Use and selection on a fine-grained scale as defined above should reflect the results of "decision-making" by males on what vegetation types should be used within their monthly home ranges.

To obtain estimates of selection of vegetation types, home range locations were determined. Monthly home ranges were constructed on maps using a minimum of 15 radio-locations per month per male to produce minimum convex polygons (Mohr 1947). Seasonal home ranges were constructed for males radio-located a minimum of 45 times per season by overlapping appropriate monthly home ranges to produce concave polygons.

Vegetation types on and near study areas, and thus within home ranges were delineated using aerial photos and ground visits. Vegetation type use (vegetation types in seasonal home ranges, and vegetation types males were radio-located in) was compared with vegetation type availability (in study areas and in monthly home ranges) using 95% family confidence intervals to indicate statistical differences (Neu et al. 1974) to obtain data on vegetation type selection. Equal weighting was given to each bird, regardless of the number of locations greater than the minima. We excluded locations of males at dancing grounds (leks) from habitat analysis.

Results

Male Prairie Sharp-tailed Grouse at CM selected summer home ranges that had greater percentages of grass-forb, grass-shrub, shrub-grass, shrub, shrub-tree, and cropland vegetation types and smaller percentages of deciduous wood, sedge meadow, open water, and shrub marsh vegetation types than were present at CM as a whole (Table 1). We had too few males radio-tagged at CM during other seasons and too few males at other study areas during any season ($<$ 4 males/study area) that were radio-located $\geq$ 45 times/season to provide additional data on seasonal home range habitat selection.

Males used grass-shrub or shrub-grass vegetation types $\geq$ 20% of the time within monthly home ranges during the spring at all study areas (Table 2). Shrub at NB, shrub-marsh at CM, and cropland at DC were also used $\geq$ 20% of the time during either daylight or night. At each area males selected cropland during daylight more frequently

TABLE 1. Average vegetation type composition (%) of the summer home ranges of five male Sharp-tailed Grouse and the composition of the CM study area.

	Vegetation type[a]										
	GF	GS	SG	SH	ST	DW	CW	SE	SM	WA	CR
Home ranges	2	6	49	9	4	2	1	6	11	0	10
Study area	1	1	10	1	1	36	2	19	9	19	1
Difference[b]	+	+	+	+	+	-	NS	-	+	-	+

[a]GF = Grass-forb; GS = shrub-grass; SH = shrub; ST = shrub-tree; DW = deciduous woods; CW = conifer woods; SE = sedge meadow; SM = shrub marsh; WA = open water; CR = cropland.
[b]Vegetation type use greater than (+) or less than (-) ($P < 0.05$) vegetation type availability within study area, using 95% confidence intervals (Neu et al. 1974). NS = difference not significant. Total radio-locations = 501.

than expected on the basis of its availability within monthly home ranges. Males used grass-shrub at DC and shrub-grass at NB less than expected (use < availability) despite their heavy use (≥ 20% of monthly radio-locations) of these vegetation types. Males roosted during the night in shrub-marsh at CM more often than expected.

Males most frequently used grass-shrub at DC and shrub-grass at NB and CM within monthly home ranges during the summer (Table 3). Shrub-marsh was also used ≥ 20% of the time at CM during the night. Vegetation types were used by males in proportion to their availability within monthly home ranges, with the exception of deciduous woods at DC and shrub-tree cover at CM, which were used less often than expected.

During the fall months males most frequently used grass-shrub or shrub-grass vegetation types within monthly ranges (Table 4). At NB and CM, both vegetation types were heavily used. Sedge meadow and shrub marsh vegetation types were used at CM consistently at night, but they were used less than expected during daylight. Males used grass-shrub cover both less than expected (at DC) and more than expected (at NB) during daylight. Grass-shrub was used less than expected at NB during daylight and at CM at night. Males used cropland more frequently than expected at all three study areas.

Males used greater percentages of deciduous woods and open coniferous woods during the winter months than during other seasons (Table 5).

TABLE 2. Average (%) vegetation type use (U) during daylight and night by male Sharp-tailed Grouse and average vegetation type availability (A) within monthly home ranges at DC, NB, and CM study areas during spring months (March, April, May) combined.[a]

Vegetation type	DC[b] daylight		NB[b] daylight		CM daylight		CM night	
	U	A	U	A	U	A	U	A[c]
Grass-forb	16	12	[d]		[d]		[d]	
Grass-shrub	24	46	19	11	16	13	12	15
Shrub-grass	3	9	45	62	42	45	48	49
Shrub	7	7	9	11	2	3	2	2
Shrub-tree	[d]		[d]		3	5	4	5
Decid. woods	14	8	11	9	6	8	8	8
Conif. woods	14	17	2	3	[d]		[d]	
Sedge meadow	[d]		2	2	8	13	3	8
Shrub marsh	[d]		[d]		9	9	20	8
Cropland	22	1	9	1	14	4	3	5
Slash	[d]		3	2	[d]		[d]	
n locations	51		125		190		85	
n birds	1		5		8			

[a]Vegetation type use greater than or less than ($P < 0.05$) vegetation type availability, using 95% confidence intervals (Neu et al. 1974), indicated by underlining.
[b]Insufficient number of radio-locations for night analysis, only daylight data shown.
[c]Percentage availability different from that during daylight because data obtained from birds with < 5 night locations per month were deleted from night analysis that month.
[d]Unavailable vegetation type within home ranges.

TABLE 3. Average (%) vegetation type use (U) during daylight and night and average vegetation type availability (A) within monthly home ranges during summer months (June, July, August) combined.[a]

Vegetation type	DC daylight U	DC daylight A	DC night U	DC night A[c]	NB[b] daylight U	NB[b] daylight A	CM daylight U	CM daylight A	CM night U	CM night A
Grass-forb	14	11	2	6	[d]		[d]		[d]	
Grass-shrub	60	57	78	61	13	10	6	9	5	9
Shrub-grass	14	17	20	19	80	78	41	47	44	47
Shrub	4	2	0	2	4	4	12	11	10	11
Shrub-tree	[d]		[d]		[d]		10	6	10	6
Decid. woods	2	8	0	8	[d]		3	2	1	2
Conif. woods	2	4	0	3	0	2	0	2	0	2
Sedge meadow	[d]		[d]		1	4	4	5	9	5
Shrub marsh	[d]		[d]		[d]		16	14	20	14
Cropland	4	1	0	1	[d]		8	4	1	4
Slash	[d]		[d]		2	2	[d]		[d]	
n locations	174		47		58		368		192	
n birds	6				3		7			

[a,b,c,d]See footnotes in Table 2.

At CM, these vegetation types were used more frequently than expected, but the 2 wetland vegetation types — sedge meadow and shrub marsh — were the most heavily used vegetation types at CM. Males continued to heavily use grass-shrub at DC and shrub-grass at NB, yet these vegetation types were selected by males less than expected on the basis of availability within monthly ranges. Shrub cover was heavily used at NB during the night. Cropland cover was used more frequently than expected at NB and CM. At DC, cropland (clover) was unavailable because of snow depths.

Discussion

Male Prairie Sharp-tailed Grouse used a variety of vegetation types throughout the year in northwestern Wisconsin. Vegetation types that were arbitrarily defined as heavily used ($\geq$ 20% use within an average home range) were grass-shrub, shrub-grass, shrub, open conifer woods, sedge meadow, shrub marsh, and cropland. This variety may reflect the variety of resource needs for the reproductive and survival tactics that males use throughout a day, a calendar season, and a year (Gratson 1988; Bergerud and Gratson 1988). For example, at CM, males often heavily used sedge

TABLE 4. Average (%) vegetation type use (U) during daylight and night and average vegetation type availability (A) within monthly home ranges during fall months (September, October, November) combined.[a]

Vegetation type	DC daylight U	DC daylight A	DC night U	DC night A	NB[b] daylight U	NB[b] daylight A	CM daylight U	CM daylight A	CM night U	CM night A
Grass-forb	10	8	13	8	[d]		[d]		[d]	
Grass-shrub	44	53	57	53	32	12	22	13	12	13
Shrub-grass	11	11	15	11	41	69	24	20	9	20
Shrub/S. tree	5	4	3	4	8	8	17	13	7	13
Decid. woods	10	5	4	5	2	1	9	9	9	9
Conif. woods	10	17	5	17	4	2	[d]		[d]	
Sedge meadow	0	1	1	1	1	2	6	21	29	21
Shrub marsh	[d]		[d]		[d]		11	22	36	22
Cropland	10	1	2	1	10	2	11	2	0	2
Slash	[d]		[d]		2	4	[d]		[d]	
n locations	236		109		104		100		51	
n birds	8				3		3			

[a,b,d]See footnotes in Table 2.

TABLE 5. Average (%) vegetation type use (U) during daylight and night and average vegetation type availability (A) within monthly home ranges during winter months (December, January, February) combined.[a]

Vegetation type	DC daylight U	DC daylight A	DC night U	DC night A	NB daylight U	NB daylight A[d]	NB night U	NB night A	CM[b] daylight U	CM[b] daylight A
Grass-forb	2	9	4	9	[c]		[c]		[c]	
Grass-shrub	30	46	32	46	9	12	5	12	9	8
Shrub-grass	8	7	10	7	37	50	31	50	12	14
Shrub	7	5	1	5	18	13	26	13	2	2
Decid. woods	16	8	16	8	14	10	16	10	12	7
Conif. woods	35	23	35	23	6	7	20	7	5	1
Sedge meadow	0	1	2	1	1	1	2	1	19	42
Shrub marsh	[c]		[c]		[c]		[c]		29	24
Cropland	2	1	0	1	15	1	0	1	12	2
Slash	[c]		[c]		0	6	[c]		[c]	
n locations	105		50		119		61		91	
n birds	4				4				4	

[a,b,c]See footnotes Table 2.

meadow and/or shrub marsh for roosting at night in the fall. An average of 65% of the night locations were in these vegetation types. In contrast, these vegetation types together were used an average of only 17% of the time during daylight hours. Gratson (1988) speculated, partly on the basis that there were fewer small mammalian prey species of Red Fox (*Vulpes vulpes*), Coyotes (*Canis latrans*), and Great-horned Owls (*Bubo virginianus*) in sedge meadows and shrub marshes, that these vegetation types were heavily used for night roosting because they were safer than surrounding upland types.

We obtained sufficient data on seasonal home range location in relation to an entire study area only at CM during the summer. These data suggested that males selected summer home ranges on CM that had disproportionately higher percentages of shrub-grass and cropland and lower percentages of deciduous woods, sedge meadows, and open water than CM as a whole. In contrast to this coarse-grained analysis, the comparison of vegetation types used to vegetation types available within monthly home ranges during the summer showed that, with the exception of an avoidance of cropland during the night, vegetation types were used in proportion to their availability. Taken alone, this fine-grained analysis of vegetation type selection provides no clues on the relative importance of particular vegetation types to males. Yet it is clear from the analysis at the seasonal level that shrub-grass (particularly) was relatively more important to males at this time of year than were the other vegetation types. It is also clear that deciduous woods, sedge meadows, and open water were relatively less important to males than were the other vegetation types. The contrast between selection at coarse-grained and fine-grained levels indicates that caution should be used in the interpretation of cover selection statistics.

It is clear from the data presented that caution should also be used in the interpretation of vegetation type analyses that rely solely on *either* vegetation type use or vegetation type selection. To illustrate the problem we again refer to the question of the relative importance of the shrub-grass vegetation type. A look at Tables 2-4 reveals that in each of the four instances that shrub-grass is used nonrandomly, it is used less than expected, indicating "avoidance". Yet this vegetation type was one of the most heavily used vegetation types at all study areas during all times of year. Of 19 data sets on shrub-grass use within monthly home ranges 11 data sets indicate that shrub-grass was heavily used ($\geq$ 20% of the time males were radio-located in it). These use data suggest to us the relatively great importance of this vegetation type to male survival and/or reproduction rather than the little importance the selection data alone might seem to indicate. Together these use and selection analyses provided a more defensible basis for determining what vegetation types were important to males, despite the sometimes apparently conflicting results.

Our results are consistent with the older studies of *T. p. campestris*, which indicate the reliance by this subspecies on open upland vegetation types, particularly between the time males begin attending dancing grounds in the spring and the time permanent snow cover arrives in the late fall

(Grange 1948; Hamerstrom and Hamerstrom 1951; Ammann 1957). Our study helps more closely define what optimum habitat composition might be, at least to male Sharp-tailed Grouse. We emphasize the importance of maintaining and encouraging open shrub-grass and grass-shrub vegetation types on the poorer, sandy soils of the present range of *T. p. campestris*. Elsewhere, stands of grasses and forbs may be sufficiently tall and dense to provide the horizontal and vertical structure that we suggest may be important in helping define good "breeding habitat".

Our study is also consistent with those that indicate a shift by Sharp-tailed Grouse to vegetation types containing trees during the winter (Grange 1947; Hamerstrom and Hamerstrom 1951; Ammann 1957). At our study areas, males continued to heavily use open upland (grass-shrub or shrub-grass at DC and NB) or open lowland (sedge meadow and shrub marsh at CM) vegetation types during much of the day, but they also used small stands of mature aspen, or more often, birch (*Betula papyrifera*). These deciduous vegetation types were used daily for foraging where cropland was unavailable and often were located in open (logged or sparsely planted) blocks of coniferous woods.

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Factors Affecting the Nesting Success of Dusky Canada Geese, *Branta canadensis occidentalis*, on the Copper River Delta, Alaska

BRUCE H. CAMPBELL

Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska 99518

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Habitat availability, use by nesting geese, and nest fate were sampled between 1982-1986 to determine how changes in habitat have affected the nesting ecology of the Dusky Canada Goose. Shrub communities have displaced much of the mixed grass/forb habitat preferred by geese for nesting. Geese have adjusted to this change and are using shrub habitats in a greater proportion than expected. The distribution of nests in shrub and open levee habitats is related to spring phenology with more nests occurring in shrub habitats in early springs. Nest success has declined since the late 1970s with predation by Brown Bears, canids, and predaceous sea birds being the primary cause of nest losses. Nest predation rates are also related to spring phenology with greater losses occurring during late springs. However, the magnitude of nest predation by the three major predators varied annually independent of spring phenology. Brown Bears were consistently responsible for about half the nest destruction while canids and predaceous seabirds were responsible for approximately 20% and 16%, respectively. No association between habitat type and overall level of nest destruction or nest destruction by specific predator was observed. While canids and avian predators may have preferences for certain habitats for foraging, the dominance of the opportunistic brown bear, which appears to have no preference as a nest predator, probably masks these preferences. Poor nest success is likely to continue unless predators are managed to benefit the Dusky Canada Goose.

Key Words: Dusky Canada Goose, *Branta canadensis occidentalis*, nesting success, nest predation, habitat use, Alaska.

The Dusky Canada Goose (*Branta canadensis occidentalis*) is numerically one of the smallest populations of Canada Geese, with mid-winter population indices ranging from about 7500-8000 in 1953 and 1985 to 28 000 in 1960 (Pacific Flyway Council 1985). They have been harvested heavily on the wintering grounds in northwestern Oregon and southwestern Washington with nearly all (95%) of the average annual mortality of 45% resulting from hunting on the wintering grounds (Chapman et al. 1969; Henny 1967). This mortality has been the primary factor limiting the size of the population (Hansen 1962).

The Dusky Canada Goose is known to nest only on the Copper River Delta, Alaska. Conditions on the nesting grounds have been in a state of flux since 1964 when the area was uplifted by a major earthquake. Prior to that time the delta was covered by wetland habitats maintained by tidal flooding (Olson 1954; Trainer 1959; Crow 1972; Potyondy et al. 1975). Extensive brackish water marshes were dominated by sedges (*Carex* spp.) and low slough levees associated with the extensive drainage system supported a mixed grass/forb plant community. Virtually all (97%) nesting occurred on the levees and nesting success was greater than 80% (Trainer 1959). The primary cause of nest loss was tidal flooding (Trainer 1959; Hansen 1961). Qualitative descriptions suggest that, while predaceous sea birds occurred on the delta, mammalian predators were not a threat to nesting geese (Olson 1954). However, as early as 1953 the potential impact of changes in habitat or predator numbers and foraging behavior on nesting geese were recognized (Olson 1954).

In March 1964, the Copper River Delta was uplifted by 2 meters (Reimnitz 1972). Tidal-maintained wetland habitats disappeared and the composition of plant communities began to change (Crow 1968; Potyondy et al. 1975). By the early 1970s a low shrub community composed primarily of Sweet Gale (*Myrica gale*), willow (*Salix* spp.) and alder (*Alnus crispa*) had become established on the levees. This community was preferred by nesting geese (Bromley 1976). Even though mammalian predators such as the coyote (*Canis latrans*) and Brown Bear (*Ursus arctos*) were common, nesting success continued to be high. Avian predators such as Glaucous-winged Gulls (*Larus glaucescens*) and Parasitic Jaegers (*Stercorarius parasiticus*) were responsible for a majority of the nest failures (Bromley 1976). Habitat changes brought predictions that nest predation would become a problem and production would limit the population (Shepherd 1965; Bromley 1976).

In the late 1970s production dropped and the population started to decline (Campbell and Timm 1983; Cornely et al. 1985). In response, harvest was reduced in 1983. Production has remained low and

the population continues to decline, confirming that factors limiting the population are now at work on the nesting grounds. In 1982 the Alaska Department of Fish and Game initiated an investigation to identify these limiting factors.

Study Area

The Copper River Delta is an approximately 650 km^2 deltaic plain at the mouth of the Copper River on the north coast of the Gulf of Alaska. The area has a maritime climate with cool summers and mild winters. Annual temperatures average 3.4° C, ranging from an average -5° C in January to 12° C in July. Precipitation is abundant, averaging 205 cm annually, including 318 cm of snowfall (Searby 1978).

The study area is located on the approximately 450 km^2 plain on the west side of the Copper River. This area is interlaced with tidal sloughs and glacial streams with numerous small, shallow ponds between drainages. Low levees are common along sloughs and streams. Prior to 1964, seasonal high tides and storm tides inundated the delta, influencing composition of plant communities and physiography. Ponds were brackish and marsh vegetation salt tolerant. Grass-forb communities dominated by sedges, Dune Grass (*Elymus arenarius*), Hair Grass (*Deschampsia beringensis*) and forbs such as Wild Iris (*Iris setosa*), Shooting Star (*Dodecatheon pulchellum*), and Marsh Fivefinger (*Potentilla palustris*) occurred on levees. Shrub cover was limited to salt tolerant Sweet Gale (*Myrica gale*). After 1964, ponds became fresh water and the composition of plant communities began to change. Communities in pond basins continued to be dominated by sedges but tall shrubs such as alder and willow became established along many of the levees. A ground cover of mosses (*Sphagnum* spp.) became established on all but the wettest sites and communities with little vertical structure developed on the drier levees of tertiary drainages. These dry sites are covered by lichens (*Cetraria* sp., *Cladina* sp., and *Peltigera* sp.), prostrate willow, and scattered low forbs such as yarrow (*Achillea* spp.). Stands of shrub-bog (*Myrica gale* and *Menyanthes trifoliata*) are common inland from the coast and are transitional between the coastal marsh and alder-Sitka Spruce (*Picea sitchenis*), Western Hemlock (*Tsuga heterophylla*) community that occurs 7-11 km from the coast. More extensive descriptions of pre-and post earthquake physiography and plant communities are provided by Trainer (1959), Crow (1968), and Potyondy et al. (1975).

Methods

Data presented in this paper were collected between 1982-1986 from nine 0.21-0.88 km^2 plots. These plots were extensively searched twice each nesting season, during the late laying or early incubation stage and again after peak of hatch. Habitat type for all nests and the number and stage of development of eggs in active nests were recorded during the first visit. Classification of habitat types was according to the categories in Table 1. Because physical configuration of habitat is a major influence on how geese select nest sites (Long 1970; Heagy and Cooke 1979; McCabe 1979), habitat classification was based primarily on physical structure. To facilitate relocation, all nests were marked and their location plotted on large scale (1:330-1:700) maps.

Nest fate was determined during the second visit. Nests in which one or more eggs hatched were considered successful. Attended nests were considered to be incubating, and unattended nests with arrested development of eggs were classified as abandoned. Nest destruction was classified as avian, canid, bear, or unknown mammal, when possible, using published characteristics of predation (Darrow 1938; Sooter 1946; Reardon 1951) and techniques developed during this study.

TABLE 1. Characteristics of habitat types used by Dusky Canada Geese for nesting on the west Copper River Delta, 1982-1986[1].

Habitat Type	Predominate Species	General Structural Characteristics
Tall Shrub	Alder (*Alnus*) and willow (*Salix*).	Taller than 120 cm.
Low Shrub	Sweetgale (*Myrica*) with occasional alder and willow.	Less than 120 cm tall.
Levee	Prostrate willow, forbs, Wild Iris (*Iris setosa*), moss (*Sphagnum* spp.), scattered low shrubs, and sedge (*Carex* spp.).	Very open, typically vegetation less than 30 cm tall with little to no overhead cover.
Meadow	Monotypic sedge meadows with scattered grass and low shrubs.	Open meadows, typically in pond basins between levees and ponds.

[1]Based on Bromley (1976) and personal communication.

Habitat types and fate for any newly discovered nests were also recorded. In 1983-1986, areas adjacent to study plots with similar habitat were searched after the peak of hatch and nest fate information used as a control to determine if the presence of field crews influenced nest success on the study plots.

Habitat maps for the study plots were developed, without correction from oblique angle of exposure, from a series of 35mm slides taken at approximately 2300 m AGL. Maps were digitized and the surface area of each habitat type or physical feature computed. These data were compared to comparable information from the 1970s (Bromley 1976 and personal communication; Potyondy et al. 1975) to identify habitat changes. Preference for habitat types of nesting geese was determined by a chi-square goodness of fit test.

Spring (April-June) weather data were obtained from the Cordova Federal Aviation Administration Station (U.S. Department of Commerce, 1982-1986) to test for relationships between weather, nest distribution by habitat type, nest success and predator activities. A weather index for each spring was calculated, following Bromley (1976), by adding the weighted deviations from normal for mean monthly temperature and precipitation. Each degree celcius and cm of precipitation above or below norm was assigned a value of +5 or -5 while each cm of deviation of snowfall above or below norm was assigned a +1 or -1 value. Large indices were considered indicative of warm, dry springs, conditions more favorable for nesting geese. These indices along with nest distribution data were used to build a logistic regression model (Agresti 1984) of the influence of weather on nest distribution. They were also used along with nest distribution, number of habitats, and year to build an ordinal loglinear logit model (Agresti 1984) of their effects on nest fate. Goodness-of-fit for the models was tested ($\alpha = 0.05$) using the likelihood ratio statistic (G^2) with the simplest model not having a significant lack of fit chosen as best. Spearman's rank correlation was used to test for a relationship between spring phenology and proportion of nests destroyed by each predator. Because a relationship between alternate prey such as lemmings or microtines and nest predation exists in other waterfowl nesting areas (Angstadt 1961; MacInnes 1962; Barry 1967; Byers 1974; Eisenhauer and Kirkpatrick 1977; Weller 1979; Summers and Underhill 1987), the small mammal population was monitored between 1983-1986. From 2-3 assessment lines, composed of 25 museum special snap traps each, were maintained on the study plots during the sampling periods. An index of the abundance, and presumably availability of small mammals, was the ratio of animals captured to trap effort. The proportion of nests destroyed by each predator were linearly regressed on this index to determine if a relationship between microtine abundance and nest predation existed.

Results

Judging from changes on the study plots, the structure and composition of habitat on the Copper River Delta has changed significantly ($\chi^2 = 38.71$, $P < 0.05$, $df = 4$) since 1974 (Table 2). While the portion of habitat composed of ponds and meadows has remained relatively constant, shrub cover has increased over ninefold and levee habitat has halved. Composition of the greatly expanded shrub habitat has also changed. Over 60% of the shrub cover is now tall shrub (> 120 cm), a habitat virtually nonexistent in 1974 (Bromley 1976). Stands of tall shrub are now common along drainages where they have displaced mixed grass/forb communities. The dramatic increase and dominance of tall shrub overshadows a 3½-fold increase in low shrub habitat which, along with tall shrubs, have displaced levee habitat. Low shrub communities often occur as transitional zones between tall shrub and levee or meadow habitats.

Nesting habitat utilization was identified from the distribution of 782 nests (Table 3). Based on a χ^2 goodness of fit test (Table 4), shrub habitats were used more frequently than expected and considered preferred while levee habitat was used less frequently than expected and was considered to be selected against by nesting geese. Meadows were used in approximate proportion to their availability. However, there was a significant ($\chi^2 = 57.96$, $P < 0.01$, $df = 12$) amount of annual variation in nest distribution. A logistic regression model, fit to the data using stepwise regression and incorporating the spring weather index and effect of habitat on nest distribution, best ($G^2 = 6.99$, $P < 0.25$, $df = 6$) explained this variation. This model indicates that the annual variation in nest

TABLE 2. Composition of habitat on Dusky Canada Goose nesting study plots on the Copper River Delta, Alaska, in 1974 and 1986.

Habitat type	Percent of area covered	
	1974	1986
Pond	15.2	13.1
Meadow	42.3	43.9
Levee	40.0	20.1
Low shrub	2.5	8.8
Tall shrub	< 0.1	14.1

TABLE 3. Distribution of Dusky Canada Goose nests by habitat type on the Copper River Delta, Alaska, 1982-1986.

Habitat Type	1982 nests	%	1983 nests	%	1984 nests	%	1985 nests	%	1986 nests	%	5-year $\bar{x}$ nests	%
Tall shrub	25	15.6	20	13.9	32	22.5	28	18.5	52	28.1	157	20.0
Low shrub	38	23.8	42	29.2	39	27.5	26	17.2	59	31.9	204	26.0
Levee	32	20.0	12	8.3	10	7.0	39	25.8	14	7.6	107	13.6
Meadow	65	40.6	70	48.6	61	43.0	58	38.4	60	32.4	314	40.0
Total	160		144		142		151		185		782	

distribution was primarily the result of weather-influenced changes in the utilization of levee and shrub habitats. During late springs, open levee habitat was used more frequently than shrub habitats, primarily low shrub, but, in years with average to early phenology, the relative frequency of nests occurring in shrub habitats was higher.

The fates of 726 nests were documented. Of these 302 were successful, 394 destroyed and 30 were abandoned. As documented elsewhere (Bromley 1976; Gotmark et al. 1984), the presence of field crews had little influence on these fates. With the exception of 1983 when nest success was significantly ($\chi^2 = 9.26$, $P < 0.05$, df = 3) greater on the study plots, nest fates were similar on control and study plots ($\chi^2_{84} = 1.42$, $\chi^2_{85} = 5.26$, ($\chi^2_{86} = 1.41$, $P > 0.05$, df = 3).

Nest success averaged about 43% (Table 5) but varied considerably between years; ranging from 7% (1985) to 88% (1984). The best fitting ($G^2 = 8.84$, $P > 0.75$, df = 12, 12) ordinal loglinear logit model indicated that weather was primary responsible for this variation. Nests were initiated earlier and much more likely to be successful during springs with favorable weather (Table 6) (success: failure odds of 7.17:1) than during springs with cool, wet weather (success: failure odds of 0.073:1).

While the magnitude of nest predation varied annually in association with spring phenology, the composition of that destruction did not. Based on 349 nests for which the predator could confidently be identified (Table 7), Brown Bears were consistently (no significant variation between years, $\chi^2 = 6.91$, $P > 0.10$, df = 4) responsible for about half of the destruction. This predation was independent of spring phenology ($r_s = 0.10$) and small mammal availability ($r = 0.01$). The proportion of total nest losses to canids averaged 20% but differed significantly ($\chi^2 = 9.03$, $P > 0.05$, df = 4) from year to year independent of spring phenology ($r_s = -0.30$) and small mammal availability ($r = 0.03$). Avian predators were responsible for an average of 16% of the total nest losses annually. Avian predation differed significantly ($\chi^2 = 66.87$, $P < 0.01$, df = 4) from year to year independent of weather ($r_s = -0.20$), and small mammal availability ($r = 0.54$).

No association between habitat and nest destruction was observed. The level of nest destruction did not differ significantly ($\chi^2 = 11.72$, $P > 0.05$, d = 19) among habitats in any year. Predators apparently had little preference for a specific habitat type for foraging. There was no significant difference (bear, $\chi^2 = 11.54$, $P > 0.05$, df = 19; canid, $\chi^2 = 28.67$, $P > 0.05$, df = 9; avian, $\chi^2 = 13.23$, $P > 0.05$, df = 15) between the actual number of nests destroyed and expected number of nests destroyed (number of nests available × predation rates) in each habitat type.

Discussion

As predicted (Crow 1968; Potyondy et al. 1975) shrub cover has continued to increase on the Copper River Delta, displacing mixed grass/forb communities. This change is reflected in habitats

TABLE 4. Habitat composition, average nest distribution by habitat type, and nesting preference/avoidance test for Dusky Canada Geese on west Copper River Delta, Alaska 1982-1986.

Habitat type	% of area	Number of nests (o_i)	Expected number of nests[1] (e_i)	Cell contribution [$\pm (o_i-e_i)^2/e_i$]	Habitat type selection
Tall shrub	14.1	157	110.3	+19.8	preferred
Low shrub	8.8	204	68.8	+265.7	preferred
Levee	20.1	107	157.2	-16.0	selected against
Meadow	43.9	314	343.3	-2.5	no preference

[1]Expected number of nests = percentage composition of habitat types X total nests.

TABLE 5. Distribution of successful and destroyed Dusky Canada Goose nests, by habitat type, on the Copper River Delta, 1982-1986.

Habitat type	1982				1983				1984				1985				1986				1982-1986 $\bar{x}$			
	N	Successful nests No.	%	Destroyed nests No.	%	N	Successful nests No.	%	Destroyed nests No.	%	N	Successful nests No.	%	Destroyed nests No.	%	N	Successful nests No.	%	Destroyed nests No.	%	N	Successful nests No.	%	Destroyed nests No.	%
Tall shrub	21	12	61.9	8	38.1	18	10	55.6	8	44.4	30	27	90.0	3	10.0	27	3	11.1	24	88.9	45	7	15.5	38	84.4	141	60	42.5	81	57.4
Low shrub	35	18	51.4	17	48.6	38	23	60.5	15	39.5	35	32	91.4	3	9.3	39	0	0.0	39	100.0	53	7	13.2	46	86.8	200	80	40.0	120	60.0
Levee	31	14	45.2	17	54.8	11	7	63.1	4	36.4	10	9	90.0	1	10.0	25	2	8.0	23	92.0	12	1	8.3	11	91.7	89	33	37.1	56	62.9
Meadow	61	34	55.7	27	44.3	62	34	54.8	28	45.2	57	48	84.2	9	15.8	44	4	9.1	40	90.1	42	9	21.4	33	78.6	266	129	48.5	137	51.5

used by nesting geese. Prior to 1964 geese nested primarily in the mixed grass/forb community (Trainer 1959).

While it is not known whether selection of nest sites was based on plant cover or relief, elevation undoubtedly influenced site selection since tidal flooding was the primary cause of nest failure (Trainer 1959; Hansen 1961). With the invasion of shrub communities came an apparent change in preference for nesting habitat. Whether this change is real and Dusky Canada Geese now prefer shrub habitat for nesting, as do some other Canada Geese (Ewaschuk and Boag 1972), or reflects their fidelity to elevated nesting sites regardless of plant cover, as suggested by Bromley (1976), is now known. With the time frame and level of nest destruction involved, the former is less plausible. Virtually all nest failure has been due to nest destruction which has been proportionately equal in all habitat types. This would seem to provide little selective advantage to geese developing a preference for certain habitat types. It is also unlikely that such selection would be expressed strongly within the last 10 years with poor nest success and production. Regardless of the reasons for nest site selection, the important point is that extensive stands of shrubs now occur on many elevated sites on the Copper River Delta and are being used heavily by nesting geese.

As is common in populations of geese nesting in northern latitudes (McEwen 1958; Barry 1962 and 1967; Uspenski 1965; Ryder 1970; MacInnes et al. 1974) and, as was previously found to be the case on the Copper River Delta (Bromley 1976), spring weather influences Dusky Canada Goose production. This influence is apparently on habitat availability, nesting energy requirements, and predator activity. Geese typically initate nests early and select sites that are, or will become snow-free first (MacInnes 1962). During late springs much of the preferred shrub habitats are unavailable due to persisting snow cover. In addition, meadows are still ice covered or flooded by snow melt. As a result, geese are forced to nest on the relatively

TABLE 6. Spring weather index, estimated peak of nest initiation, and nest success for the Dusky Canada Goose on the Copper River Delta, 1982-1986.

Year	Weather index	Peak of nest initiation	Nest success
1982	+2.2	—	49.2
1983	+51.1	5/6-10	51.9
1984	+110.0	5/3-8	75.8
1985	-133.6	5/27-6/1	8.9
1986	+66.8	5/6-12	11.4

TABLE 7. Types of nest destruction for Dusky Canada Goose nests of known fate on the Copper River Delta, 1982-1986.

		Types and composition of destruction			
Year	N	Brown Bear (%)	Canid (%)	Unknown Mammal (%)	Avian
1982	55	36.4	14.5	1.8	47.3
1983	41	61.0	17.1	12.2	9.8
1984	15	46.7	26.7	13.3	13.3
1985	126	49.2	27.0	12.7	11.1
1986	112	55.4	13.4	23.3	8.0
Total/$\bar{x}$	349	50.4	19.5	14.3	15.8

open drainage levees that have become snow- and ice-free. While their reproductive potential may not be affected by this change in habitat use (Jackson et al. 1988; MacInnes and Dunn 1988), nest fate is. The combined effect of little overhead cover for nests on levees and retarded development of this cover leaves nests exposed to predators. In addition, the greater energy requirements of maintaining nests during late springs (Bromley 1985) forces incubating geese to make frequent or extended trips from nests to forage, reducing viability of eggs and further exposing nests to predators.

While numbers of both large mammalian and avian predators have increased (Shepherd 1966; Islieb and Kessel 1973; Patten and Patten 1979; Campbell and Griese 1987, unpublished report, Alaska Department of Fish and Game), the spring phenology-related activities of Brown Bears appear to have the greatest affect on nest success. Arrival of immature bears and females with offspring, the age and reproductive classes most responsible for nest losses (Campbell and Rothe 1986), on the nesting grounds appears to be associated with leaf emergence. This may coincide with the availability of preferred plant food items. Wielgus (1986) found that spring movements by female bears with young were closely tied to the availability of plant food items. Quimby and Snarski (1974) and Atwell et al. (1980) demonstrated that the availability of lush sedge/forb meadows, one of the predominant habitat types on the delta, affected seasonal home range use. It is also possible that female bears with offspring and immature animals move to the coastal delta for security in spring. Because adult male and estrus female bears are not as common on the nesting grounds (Campbell and Rothe 1986; Campbell et al. 1987), the security of family groups and immature animals may be greater there. Security from conspecifics is known to influence seasonal home ranges and habitat use of Brown Bears in other areas (Pearson 1975; Gebhard 1982; Nagy et al. 1983; Knight et al. 1986).

The dominance of Brown Bears as nest predators may have precluded identification of relationships between other predators and the environment. The apparent lack of relationship between canid predation and microtine availability is surprising given the importance of microtines in diets of northern latitude Coyotes (Todd and Keith 1976; Todd 1985; Moore and Miller 1986). It is possible that microtine availability, as measured in this investigation, is not a good indication of the relationship between alternative prey availability and Coyote predation. Also, the magnitude and distribution of avian predation of goose nests on the delta is surprisingly low and evenly dispersed among habitat types. The increase in Parasitic Jaeger and Glaucous-winged Gull numbers, both known major predators of goose nests (Angstadt 1961; MacInnes 1962; Barry 1965 and 1967; Mickelson 1975), suggests that losses to avian predators should be much greater than observed. Since habitat can influence the distribution of nest predation by avian predators (Hanson and Browning 1959), losses might also be expected to correlate with habitat types. Bromley (1976) speculated that avian predators would be disproportionately more active in habitats preferred by nesting geese because of the abundance of nests. While a slightly higher than expected rate of nest losses in shrub habitats hints at such a relationship, little association between habitat and avian predation was observed during this study. Either avian predators forage differently on the delta than elsewhere or evidence of their predation on goose nests is not obvious.

In conclusion, the dominance of shrub habitats will likely continue to increase as secondary succession moves toward a tall shrub/forest climax. This should not be a problem for the Dusky Canada Goose as it has accepted shrub cover as nesting habitat. Severe nest predation, on the other hand, is a threat to the future of the goose. This threat is compounded by the generalist nature of the predators. The lack of association

between predation and habitat types plus large activity ranges typical of the predator species involved would likely limit the effectiveness of habitat management as a method of reducing nest predation. Consequently, the most feasible solution appears to be predator population management. Such management is expensive and, in some cases, may be biologically or sociologically unacceptable. The potential of any proposed management scheme to increase goose production as well as the public's willingness to make long-term commitments to expensive artificial maintenance of the goose population, at the cost of other wildlife species, needs to be thoroughly explored and defined before intensive predator population management is initiated on the Copper River Delta.

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A Breeding Ground Survey of Atlantic Flyway Canada Geese, *Branta canadensis*, in Northern Quebec

RICHARD A. MALECKI[1] and ROBERT E. TROST[2]

[1]New York Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, Fernow Hall, Cornell University, Ithaca, New York 14853.
[2]South Carolina Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, 308 Long Hall, Clemson University, Clemson, South Carolina 29634.

Malecki, Richard A., and Robert E. Trost. 1990. A breeding ground survey of Atlantic flyway Canada Geese, *Branta canadensis*, in Northern Quebec. Canadian Field-Naturalist 104(4): 575–578.

An aerial survey of Canada Geese (*Branta canadensis*) conducted in northern Quebec in late May-early June 1988 provided an estimate of 157 122 breeding pairs, about 90% of which occurred in the Ungava peninsula and southern Ungava Bay region. Densities averaging 1.63 pairs/km^2 were found in coastal habitat along the Ungava peninsula. Breeding geese in this region are affiliated with the Atlantic flyway and our estimate suggests that we have accounted for a major portion of the northern breeding component of this population.

Key Words: Canada Geese, *Branta canadensis*, aerial survey, breeding pairs, Quebec.

Canada Geese (*Branta canadensis*) in the Atlantic flyway [eastern North America: one of four bioadministrative units conceived of in the 1940s to facilitate management of waterfowl; it includes 17 states and representation from Ontario, Quebec and the Maritime Provinces] comprise almost 1/3 of the continental population, numbering about 800 000 during the mid-winter period (1983-1988 average, U.S. Fish and Wildlife Service Migratory Bird Management Office). The most abundant waterfowl species in the flyway, over 400 000 Canada Geese are harvested annually by sport and subsistence hunters. While the population remains viable, dramatic shifts in the wintering distribution of birds from the southern portions of the range to northern areas has caused concern among managers interested in maintaining an equitable distribution of this resource (Trost and Malecki 1985). Declines in mid-winter numbers attributed to low reproductive success and high harvest levels have recently intensified this concern.

Little information is currently available to adequately assess annual productivity of Atlantic flyway Canada Geese. Satellite imagery is used to evaluate weather and habitat conditions in sub-arctic areas during the onset of nesting in spring, while ratios of immature to adult birds in the harvest provide an "after-the-fact" index to recruitment. The initiation of a breeding ground survey for nesting Canada Geese in northern Quebec would supply direct information on breeding success, as well as providing better knowledge on breeding distribution and density.

The breeding range of migrant Canada Geese in the Atlantic flyway extends from the eastern edge of Hudson and James Bays, bordering the province of Quebec, across eastern Canada to the coastal regions of Labrador and Newfoundland (Bellrose 1976). Aerial surveys conducted by Kaczynski and Chamberlain (1968) in the early to mid-1960s set the southern limit of this range at about the 50th parallel. Their work also identified the Ungava peninsula of northern Quebec as the primary nesting area for Atlantic flyway geese.

The aerial survey work of Kaczynski and Chamberlain (1968) represents the most significant effort to date to document the distribution of Atlantic flyway geese on their breeding ground. Although their surveys were extensive, they must be considered exploratory because large portions of the central and northern regions of northern Quebec were not surveyed and aerial routes were flown at altitudes often in excess of 300 feet during July and August when broods were present. Visibility of family groups was a recognized problem, especially among different habitat types. More importantly, reference to breeding geese is vague; data were compiled using geese seen per square mile, where pairs with broods were given an average value of 6 (2 adults and 4 young) and combined with other geese seen. Other surveys of note include work by Gillespie and Wetmore (1974) who sampled breeding geese in conjunction with other waterfowl over a 72 000 mi^2 area in northeastern Quebec and Labrador from 1970-1972, and Bordage (1988), who identified breeding pairs of geese in a 100 000 km^2 study area for Black Ducks (*Anas rubripes*) in central Quebec.

Extensive banding of flightless geese in the coastal regions of the Ungava peninsula during 1965-1968 indicated that large numbers of molting birds associated with the Mississippi flyway occur there (J. D. Heyland and L. Garrard, Quebec

Wildlife Service, unpublished report, 1978). Consequently, there remained much uncertainty regarding the actual importance of this region to nesting geese, the value of the vast boreal forest habitat south of the peninsula, and the extent to which the breeding population may have shifted in the 20 years since the last survey was completed.

Methods

The survey area totalled 825 226 km^2 and included all of northern Quebec bounded by 64° longitude to the east, the Ontario-Quebec border to the west, and 50° latitude to the south (Figure 1). Twenty transects, each approximately 193 km in length, were spaced perpendicular to the coastline at 97 km intervals from north to south within the study area. We surveyed all or part of 18 routes (Figure 1), totalling 3368 km, from 23 May-3 June 1988. Each line was flown with a Cessna 206 aircraft at air speeds of 120-170 km/hr and at altitudes of 24-36 m. Two observers recorded the numbers of single and paired geese sighted within 100 m on each side of the aircraft. The breeding behavior of geese, typified by a strong pair bond and attachment to the nest site, helps assure that single and pair sightings indicate nesting geese (Malecki et al. 1981). However, an unknown number of non-productive pairs undoubtedly were included in our sample.

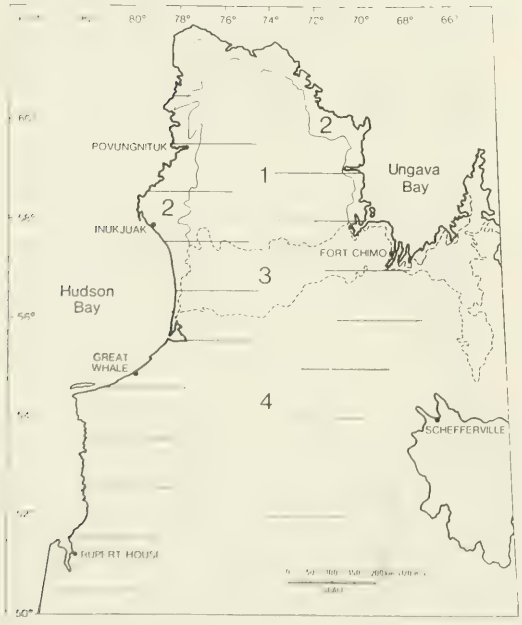

FIGURE 1. Study area in northern Quebec showing aerial routes used to survey breeding Canada Geese.

We analyzed the data using physiographic boundaries from previous work of Gilbert et al. (1985) (Figure 1). *Region 1* included much of the Ungava peninsula typified by treeless low hills (< 30 m above sea level) where granitic bedrock is exposed over the majority of the surface. Lichens dominate the vegetation, with low shrubs, such as willow (*Salix* spp.) and alder (*Alnus* spp.) occurring in sheltered areas. *Region 2* included coastal areas of the Ungava peninsula characterized by lower relief and numerous potholes and ephemeral ponds resulting from snowmelt and the presence of permafrost near the ground surface. *Region 3* is a transition between tundra and northern forest conditions. Lichen and heath-like plants cover much of the bedrock outcrop typical of this landscape, while stunted Black Spruce (*Picea mariana*) and Tamarack (*Larus laricina*) are confined to moist soils in sheltered depressions. The relatively flat relief varies in elevation from 90 to 300 m above sea level. *Region 4* is a diverse boreal zone. In the northern portion, lichens cover 60-80% of the surface, while 20-40% of this area supports the growth of Black Spruce. Progressing southward the vegetation grades into a more predominant open spruce forest which is diversified by Tamarack, Balsam-Fir (*Populus balsamifera* and White Spruce (*Picea glauca*). Mosses and small shrubs predominate in bogs, marshes, and along stream drainages. Elevations range from 90 to 300 m throughout much of the region.

Numbers of breeding pairs of geese were estimated following the procedures described by Martin et al. (1979) for the May waterfowl surveys conducted annually by the U.S. Fish and Wildlife Service and the Canadian Wildlife Service.

Results

Our breeding pair estimate for the 4 regions surveyed totaled 157 122 (S.E. = 17 424 (Table 1). The occurrence and approximate distribution of most single and pair sightings, which we used to derive this estimate, is shown in Figure 2. Fifty-six percent of the breeding pair estimate occurred in Region 2, which comprised only 7% of the survey area. The density of birds in this area averaged 1.63 pairs/km^2. Regions 1 and 3 comprised 25% of the survey area and accounted for 24% and 9% of the breeding pair estimate, respectively. Densities in these two regions averaged 0.30 and 0.18 pairs/km^2. Only 11% of the estimate occurred in Region 4, which contained 68% of the survey area. Here, breeding densities averaged 0.03 pairs/km^2.

Discussion

We estimate that about 90% of Canada Geese breeding in northern Quebec occurred in the

TABLE 1. Breeding pairs of Canada geese estimated from stratified aerial transects flown in northern Quebec, 1988.

Region	Area (km^2)	Transect area (km^2)	Breeding pair density (n/km^2)	Breeding pair estimate (n)	(S.E.)
1	124 372	285	0.30	37 312	10 354
2	54 092	119	1.63	88 170	12 939
3	81 585	171	0.18	14 685	5 195
4	565 177	780	0.03	16 955	1 410
Total	825 226	1355		157 122	17 424

Ungava peninsula and southern Ungava Bay reigon. More specifically, the majority of nesting pairs appeared concentrated along the coastal habitat bordering this area. A topographic "saddle" or trough that extends from Hudson Bay to Ungava Bay across the lower portion of Region 1, also appears to support higher densities of breeding geese.

Kaczynski and Chamberlain (1968) identified the Ungava region as containing the highest densities of geese in eastern Canada. Two of their strata located on each side of the Ungava peninsula totaled 10.7% of the approximately 450 500 mi^2 survey area and contained about 66% of their annual estimate for the periods 1956 and 1962-1966. They concluded that the estimated number of geese in Canada east of James and Hudson Bays approximated the number accounted for by the Atlantic flyway winter survey and kill estimates. However, the extent to which the two populations were the same was unknown. Returns from adult geese with young banded in 1986 and 1987 in the coastal areas near Fort Chimo and Povungnituk indicate that the birds surveyed are affiliated with the Atlantic population (Malecki, unpublished report).

The 1987-1988 mid-winter estimate for Atlantic flyway Canada Geese was 713 400 (U.S. Fish and Wildlife Service Migratory Bird Management Office). Assuming that about 100 000 of these birds are "resident" geese that breed south of the 47th parallel (Atlantic Flyway Canada Goose Committee, Unpublished Report, 1987), then a conservative estimate of 600 000 birds returned in

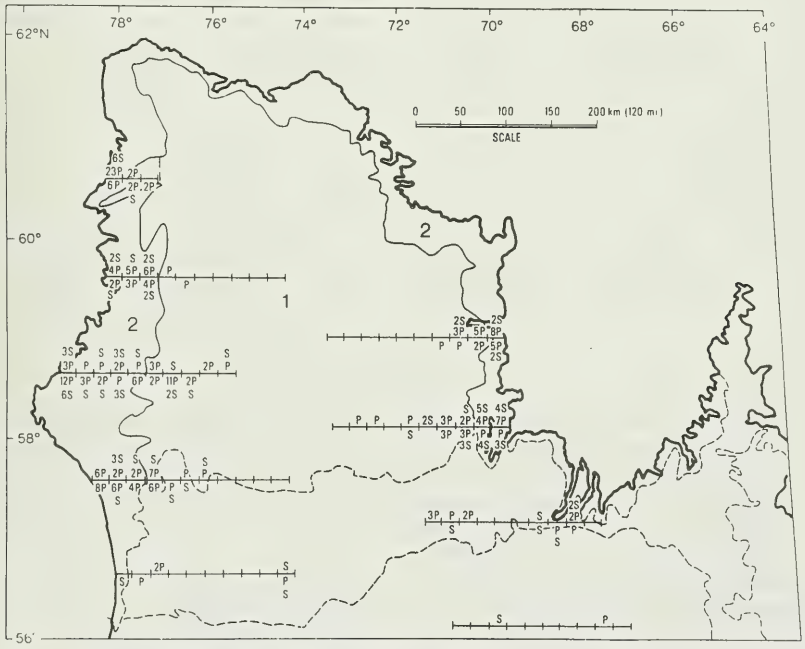

FIGURE 2. Single (S) and pair (P) sightings of Canada geese observed along transects flown in Regions 1-3, where 90% of the breeding pair estimate occurred.

the spring of 1988 to northern breeding areas. If we further assume: (1) a post-season age structure in the population of 55% adults (≥ 3 years old), 20% 2-year-olds, and 25% immatures as described by Raveling and Lumsden (1977) for the Mississippi Valley population, (2) that few 2-year-old geese nest (D. Rusch, U.S. Fish and Wildlife Service, personal communication), and (3) that about 80% of the adults nest (Bellrose 1976), then we can estimate a breeding population of 264 000 individuals or 132 000 pairs.

Our survey estimate of 157 122 pairs, uncorrected for visibility bias, and probably inflated by the inclusion of non-breeding pairs, suggests that we have accounted for a major portion of the northern breeding component of Atlantic flyway geese. This is further substantiated by the findings of Kaczynski and Chamberlain (1968), who conducted a more extensive survey and identified no other regions containing significant densities of birds. Data on spring populations of geese in Newfoundland and Labrador are interpreted by Erskine (1987) as indicative of a significant breeding component in this eastern region of the flyway. His estimates, in excess of 100 000 birds, including non-breeders and subadults, suggest that further survey work in this area may be warranted.

The management of Canada Geese traditionally has been based on the definition of populations using wintering ground affiliations. In the Atlantic flyway, Menkens and Malecki (Unpublished Report, 1989) have shown that populations or subpopulations defined during the winter are likely to be comprised of individuals from several breeding populations, each of which may require different management strategies. The refinement of future management actions for geese, therefore, requires that increasing emphasis be placed on defining breeding populations, their distribution, and factors influencing their numbers. The survey results reported here are a preliminary step in that direction. Further stratification and optimum allocation of the sample design is now possible based on these results, allowing greater precision in the estimates.

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Age of Harbour Seals, *Phoca vitulina concolor*, Wintering in Southern New England

ANDREW A. WHITMAN[1] and P. MICHAEL PAYNE

Manomet Bird Observatory, Marine Mammal and Seabird Studies, Box 936, Manomet, Massachusetts 02345
[1]Present address: Department of Wildlife Resources, University of Maine, Orono, Maine 04469

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Harbour Seals (*Phoca vitulina concolor*) wintering in southern New England were aged using a known relationship between track-width and seal age. Ninety-five percent (N = 256) of the seals in Cape Cod, Massachusetts were determined to be juveniles and subadults (< 4 years). Juveniles (< 1 year) were likely underestimated by this method in this region. It is suggested that seasonal segregation of Harbour Seals throughout New England may result from age-related competition for hauling-out sites nearer the preferred pupping ledges and age-related differences in food requirements.

Key Words: Harbour Seals, *Phoca vitulina*, track-width, age-determination, Massachusetts.

The Harbour Seal (*Phoca vitulina concolor*) occurs in southern New England, south of Maine, seasonally from late September until May (Schneider and Payne 1983). In the latter month they move north to Maine and eastern Canada prior to the pupping season. The number of seals that winter throughout southern New England has more than doubled since the passage of the Marine Mammal Protection Act in 1972 (Payne and Schneider 1984) to the current minimum estimate of 4 000-4 500 seals (Payne and Selzer 1989). This increased abundance has resulted in a greater number of seals becoming entangled in fishing gear and increased the potential for competition with fishermen for limited fish resources (Gilbert and Wynne 1984). The extent of the competition between seals and fishermen requires not only knowledge of the population size but also of the age-structure of the population and of the age-specific requirements of individual seals. Juvenile (< 1 year of age) and subadult (1-4 years of age) seals are entangled in fishing gear more often than adults (Gilbert and Wynne 1984). Subadult Harbour Seals also have greater energetic needs, per unit body weight, than adults (Ashwell-Erickson and Elsner 1981). Harwood and Greenwood (1985) suggested that the most important determinant of the total energy requirements of a seal population is the frequency distribution of weight classes in that population, which is in large part age-dependent. The purpose of this study was to determine the age-structure of the Harbour Seals that winter in southern New England.

Methods

Pinnipeds are most frequently aged by counting growth layers of dentine in the canine teeth from collected animals (Driscoll et al. 1985). The limited number of seals in southern New England and their legally protected status preclude the taking of large numbers of specimens necessary for an adequate sample size using this technique. An alternative method was developed by Reijnders (1975) who found a close correlation between the size of the seal and track-width on sand (measured as the smallest distance between imprints of the left and right fore-flipper) and, roughly, the age when only age classes are distinguished. Reijnders used this method to determine the age structure of a Harbour Seal, *P. v. vitulina*, population in the Dutch Wadden Sea (Reijnders 1976). He found that seals could be reliably separated as juveniles (< 1 yr), subadults (< 4 yrs) and adults (> 4 yrs). Similarly, Vaughan (1978) measured pup production using track-width as an indicator of age.

We measured 256 seal tracks at three locations on outer Cape Cod, Massachusetts: Monomoy Island National Wildlife Refuge and its adjacent shoals (Monomoy Island), Jeremy Point, and Race Point (see Figure 1) during January-February 1985 and 1986. At these locations, seals haul out on a sandy substrate which is suitable for measuring track-width. Approximately 50 percent of the seals wintering in southern New England haul out at these three locations (Payne and Selzer 1989); therefore the age-structure derived from measuring track-widths at these locations is assumed to be representative of seals throughout the southern New England seal population. We measured seal tracks at low tide after the seals had re-entered the water. By walking parallel to the waterline we were able to obtain track-widths without risk of duplicating a measurement from any individual seal. The track measurements were grouped into age-classes which are easily separated

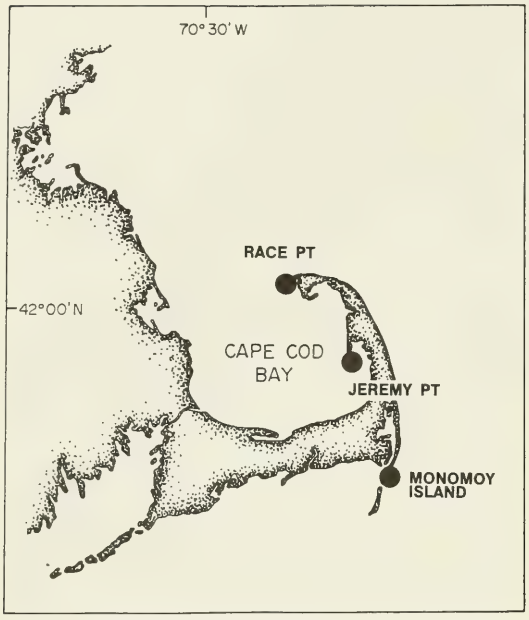

FIGURE 1. Location of the three largest haulout sites on Cape Cod, Massachusetts.

using Reijnders (1975) relationship between track-width and age. We consider this relationship applicable to *P. v. concolor,* because adult *P. v. concolor* are athe same size as adult *P. v. vitulina* (Boulva and McLaren 1979), and because length-weight data (for each age group) for *P. v. concolor* (from Boulva 1971) fall within the range for *P. v. vitulina* (from Bonner 1979).

Results

Ninety-four percent (n = 243) of the track-widths measured were from known juvenile and subadult seals if considered a single class (Table 1). The mean track width ($\bar{x} = 43.7 \pm 0.75$ cm) indicates an average seal age of between one and two years. Less than two percent (n = 3) of the total number of track-widths (N = 256) were from seals that were unquestionably juveniles (track-width ≤ 32.0 cm, Table 1). Approximately four percent (n = 9) of the measured tracks were from seals of known adult size (Table 1).

Discussion

The low number of measurements we recorded from juvenile seals is probably due to the age of these seals in months, relative to the mid-winter timing of our study. Seals disperse into southern New England during autumn following the pupping season (Payne and Schneider 1984; Rosenfeld et al. 1988), which occurs in Maine from mid-May to mid-June (Wilson 1978). Therefore the tracks we measured were from seals five to seven months of age. Reijnders' (1975) juvenile age category was based on track measurements from one-month-old pups. We could not distinguish the track-width of a juvenile seal, five to seven months of age, from those of an older, subadult seal using this technique. Therefore, the number of juvenile seals in our study area was underestimated using Reijnders' method.

The small sample of measured tracks from adult seals likely reflects the total percentage of seals from this age category in our study area. Geraci et al. (1982) determined the age of 445 seals that died along the southern New England coast from late 1979 through fall 1980 during an Influenza A epidemic. Ninety percent of the dead seals were under 3 years of age; males and females in equal numbers (Geraci et al. 1982). It is apparent from the present data and the results of previous studies (Geraci et al. 1982; Payne and Schneider 1984) that the observed increase in the number of Harbour Seals in southern New England has been due primarily to the southward dispersion of non-breeding juvenile and subadult seals from Maine rookeries. There are presently no pupping ledges in New England south of Maine (Rosenfeld et al. 1988; Payne and Selzer 1989).

Traditional views suggest that dispersion results from competition for breeding sites, space or food (Dobson 1982); also dominance behavior affects the spatial relationships and age-related movements of many mammals (Wilson 1974; Dobson 1982). Sullivan (1982) found that Harbour Seals occupying rock haulout sites form dominance hierarchies based on size and sex, territorial adult males dominating all other age and sex categories and protecting preferred sites. In our study areas, we believe that dominant males displace subadults of both sexes from rock haulout sites following

TABLE 1. Age structure (based on track-width measurements) of Harbour Seals wintering in southern New England during January-February, 1985 and 1986.

Track-width[a]	Age category[a]	N	Percent of sample
< 32 cm	juvenile	3	1.2
32.1-36.0 cm[b]		21	8.2
36.1-55 cm	subadult	219	85.6
55.1-56.0 cm[b]		4	1.6
> 56.1 cm	adult	9	3.4
Mean track-width = 43.7 ± 0.75[c]			

[a]Track-width intervals and Age categories after Reijnders (1975)
[b]Seal tracks within these measurements could not be classified into an age group with 95% confidence using Reijnders' (1975) method.
[c]95% Confidence Interval.

weaning, when competition for females and conflicts between seals of both sexes are most intense (Davis and Renouf 1987), precipitating the autumnal movement into southern New England. Non-breeding, socially subordinate subadult and juvenile seals are pushed to the perimeter of the breeding range where progressively smaller animals partition the suboptimal hauling-out locations. This social displacement of subordinate seals by dominants could explain the age-related movement during autumn and the extremely high percentage of juvenile and subadult harbour seals which appear in our study area.

The late autumn movement of young Harbour Seals also coincides with a strong offshore movement of fish in eastern Maine (MacDonald et al. 1984). If competition for food or inexperience at foraging are factors, young Harbour Seals may find the food resources in Maine limiting at this time and the pressure to disperse intensified. Food consumption rates in the winter nearly double over summer rates (Ashwell-Erickson and Elsner 1981). These factors could be particularly intense for juveniles, as first-year seals need four times the food resources per unit body weight than do adults. Thus, the age-related dispersal of predominantly young seals into southern New England is possibly dependent on both adult-subadult competition nearer preferred ledges within the present pupping range of seals in New England and the higher energy requirements of juvenile seals.

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Notes

Evaluation of Cranial and Antler Characteristics to Determine Sex of Mountain Caribou, *Rangifer tarandus*

DONALD R. JOHNSON[1] and DAVID W. NAGORSEN[2]

[1]Department of Biological Sciences, University of Idaho, Moscow, Idaho 83843
[2]Vertebrate Unit, Royal British Columbia Museum, Victoria, British Columbia V8V 1X4

Johnson, Donald R., and David W. Nagorsen. 1990. Evaluation of cranial and antler characteristics to determine sex of Mountain Caribou, *Rangifer tarandus*. Canadian Field-Naturalist 104(4): 583–584.

Pedicle diameter and antler length can be used to discriminate sex of adult (> 2 yrs) Mountain Caribou. These traits as well as dentary length will identify yearling and adult males. Of these characters, only dentary length separated yearling males from adult females. We lacked sufficient samples to attempt discrimination of yearling from adult females.

Key Words: Mountain Caribou, *Rangifer tarandus*, dentary length, pedicle diameter, antler length, sex differentiation.

Although trained observers can identify some sex/age groups of Caribou (*Rangifer tarandus*) in the field, adult females and subadult males cannot be distinguished with certainty from body or antler size (Kelsall 1968; Fuller and Keith 1980). Wildlife biologists and museum personnel face the same uncertainty in determining the sex of caribou when only cranial material is available.

Length of the dentary bone was used in several studies to distinguish the sex and age of Caribou. Bergerud (1974), Miller (1974), and Parker (1981) confirmed that the sexes of mature Barren Ground and Woodland Caribou exhibited little or no overlap in dentary length. There was however broad overlap in dentary length between males and females of younger age classes.

Pedicle diameter and antler length have been used as aging criteria. Wolleback (1926: 33) reported that pedicle diameter of reindeer increased with age and differed between the sexes because of antler size. Fuller and Keith (1980) found a positive relationship between antler length and age of Woodland Caribou from north-eastern Alberta.

We evaluated the reliability of these traits to discriminate the sex of Mountain Caribou from the Selkirk Mountains of southeastern British Columbia and northern Idaho.

Methods

We assessed three characters: length of the dentary bone (distance from the anterior edge to posterior rim of the ramus), length of the major axis of the pedicle, and antler length (linear distance from burr to tip, Figure 1). All animals in the sample had either hard antlers, or, in some females, one or more vestigial pedicles. We took measurements from the left side unless the left pedicle was vestigial or the left antler was shorter than the right. We obtained only a few estimates of age based on counts of cementum annuli because of the dried condition of the skulls. Cementum is often lost from teeth extracted from dried skulls, resulting in an underestimate of true age (P. Wakkinen, personal communication). Therefore, skulls were assigned to four age classes (< 1, 1, 2, or > 2 years) according to the pattern of molar eruption (Bergerud 1970). We used Kruskal-Wallace ANOVA tests to evaluate differences in measurements between sex/age groups.

Results and Discussion

Our analysis was based on 22 skulls, of which 19 are in museums (Appendix); the latter represent all known specimens of this population. Despite small sample sizes, we are able to make certain definitive statements regarding the use of these traits to distinguish sex of mountain caribou.

The sex of adults (> 2 years of age) can be determined using any of these traits (Table 1). In all cases values of adult males were significantly greater than those of adult females ($P < 0.01$). These traits also differentiated yearling from adult males ($P < 0.02$). We lacked a sufficient sample to test for differences between yearling and adult females. Of these traits, only dentary length separated adult females from yearling males ($P < 0.04$), that of females being larger (Table 1). We doubt that any of these traits can be used to identify the sex of calves.

Bergerud (1964), Miller (1974) and Parker (1981) have plotted dentary growth rates of Newfoundland, Kaminuriak and Labrador populations respectively.

TABLE 1. Mean length (range) of dentary bone (mm), pedicle diameter (mm) and antler length (cm) of Caribou from southeastern British Columbia and northern Idaho.

Sex	Age (yrs)	Dentary Length	Pedicle Diameter	Antler Length
F	> 2	275.0 (255-291) N = 7	24.2 (21-28) N = 6	28.4 (18-35.5) N = 6
M	> 2	300.0 (188-311) N = 9	35.0 (34-40) N = 5	55.0 (44.5-75.5) N = 7
M	1	253.7 (245-265) N = 3	21.0 (18-23) N = 3	22.8 (10.5-35) N = 3

(Parker's study was limited to females.) The rate of dentary growth in our sample was similar to that of the Newfoundland population and accelerated in comparison with that of Kaminuriak Caribou. Dentary growth of yearling males (mean 254 mm. Table 1) for example was as great as that of Kaminuriak males 2 years of age (Miller 1974, p. 31).

Because illegal hunting is primarily directed against larger males of the Selkirk population (Johnson 1985), few males now reach full maturity. We note for example antler lengths of specimens collected before 1900 sometimes exceeded 75 cm (79 cm, Boundary County Museum and 89 cm, D. Boswell collection). The longest antler lengths of males recovered in recent years are shorter (72.5 cm, University of Idaho and 75 cm, D. Freddy Collection).

FIGURE 1. Cranial and antler characteristics for caribou evaluated. A = dentary length, B = pedicle diameter, and C = antler length.

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Appendix

Catalogue numbers of 19 museum specimens examined at the Royal British Columbia Museum (BCPM), University of Idaho (UIDA) and Selkirk College (SC). Sex based on tag information; age estimates based on molar eruption. AGE > 2 yrs, females: BCPM 6977, 6979, 11088, 11841; UIDA 10228603, 10228604; males: BCPM 10225, 6980, 6978, 9783, 9784, 15309; SC 463. AGE 2 yrs, females BCPM 15230. AGE 1 yr, males BCPM 6976, 11178, UIDA 10228602; sex ? BCPM 11402. AGE < 1, sex? UIDA 10228601. Three additional specimens that were examined from the Boundary County Museum and from the private collections of D. Boswell and D. Freddy do not have numbers assigned.

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Unusual Numbers of Porcupines, *Erethizon dorsatum*, Observed Denning Together

DAVID F. G. WOLFE

P.O. Box 1572, Anchorage, Alaska 99510

Wolfe, David F. G. 1990. Unusual numbers of Porcupines, *Erethizon dorsatum*, observed denning together. Canadian Field-Naturalist 104(4): 585.

Eight Porcupines (*Erethizon dorsatum*) were observed simultaneously occupying a den in northern Vermont. Previously documented gregarious denning observations are reviewed. Climatic conditions are proposed as an explanation of such congregations.

Key Words: Porcupine, *Erethizon dorsatum*, gregarious denning, Vermont.

Several authors have reported observing Porcupines (*Erethizon dorsatum*) denning in pairs (Brander 1973; Curtis and Kozicky 1944; Dodge and Barnes 1975; Roze 1987). Such pairs usually consist of a male and a female (Curtis and Kozicky 1944; Roze 1987) denning during mating season (Dodge and Barnes 1975) or a female and a juvenile in winter (Tenneson and Oring 1985). Additionally, Curtis and Kozicky (1944) found three Porcupines in a hollow log in Maine, and Dodge (1967) reported six denning in an abandoned house in New Hampshire. Taylor (1935) reported sign indicating that 3-10 individuals may use larger dens at the same time, but such congregations were not verified. This note documents the simultaneous occupation of a den by at least eight Porcupines.

During January, 1986, I entered six porcupine dens in a rock outcrop 5 km north of East Johnson, Vermont. I found three, five, and eight Porcupines on 18, 21, and 26 January, respectively, in the largest (main cavern: 2.6 m(h) × 2.3 m(w) × 3.3 m (d)) of these dens. I found two of the eight animals on 26 January hiding in narrow passageways; these were located with a 35 mm flash-equipped camera while photographing the den. I suspect more Porcupines were present in similar passages, but were obscured from view by the Porcupines at the passage entrance.

Escape from inclement conditions is thought to be a primary reason for winter denning among porcupines (Shapiro 1949; Smith 1979; Taylor 1935). Roze (1987: 985) has suggested that Porcupines share dens only when forced to; this may have been the case with this colony. Severe weather conditions, including ice storms, thaws, and record-breaking snowfalls, occurred during this study, with a temperature change of -27 to 8° C recorded for the three days prior to these observations. Such variable weather may have forced this colony to congregate (although cohabitation, in lesser congregations, appeared common in this denning area) in their dens through the observation period.

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Foraging Success Rates of North American River Otters, *Lutra canadensis*, Hunting Alone and Hunting in Pairs

ANNAMARIE L. BECKEL

Center for Limnology, University of Wisconsin-Madison, Madison, Wisconsin 53706
Mailing address: UW Trout Lake Station, 10810 County N, Boulder Junction, Wisconsin 54512

Beckel, Annamarie L. 1990. Foraging success rates of North American River Otters, *Lutra canadensis*, hunting alone and hunting in pairs. Canadian Field-Naturalist 104(4): 586–588.

The foraging behavior of North American River Otters, *Lutra canadensis*, living near the Tomahawk River in northcentral Wisconsin was observed during winter and early spring, 1977. I compared percent successful dives, duration of dives, and duration of eating (an index of prey size) by otters hunting alone and those hunting in pairs to determine whether hunting in pairs affected individual foraging success. Otters preyed primarily on fish (7.5-20 cm long) and I observed no food sharing or fighting over food. Animals hunting together usually remained within a few meters of each other, but did not dive together or coordinate their hunting efforts. Otters hunting alone had significantly higher success rates than animals hunting in pairs, but otters hunting together tended to spend longer times consuming their prey. There were no significant differences between the durations of dives of otters foraging alone and those of animals foraging together or between the durations of successful dives and unsuccessful dives. Durations of dives were unrelated to the size of fish caught.

Key Words: North American River Otter, *Lutra canadensis*, hunting behavior, Wisconsin.

North American River Otters (*Lutra canadensis*) are rarely observed for long under natural conditions, and although a great deal is known about what otters eat (Greer 1955; Hamilton 1961; Knudsen and Hale 1968; Lagler and Ostenson 1942; Ryder 1955; Sheldon and Toll 1964; Toweill 1974), little is known about their actual hunting and feeding behavior. *L. canadensis* live both singly and in social groups, the basic social unit being the family group, consisting of a female and her unweaned young; family groups occasionally combine to form larger groups and single otters commonly join family groups at least temporarily (Melquist and Hornocker 1983). Otters within groups, including unrelated adults, devote significant amounts of time and energy to affiliative social interactions such as social grooming and wrestling (Beckel 1982). Mixed-sex and same-sex associations of adult otters occur both during and outside the breeding season (Erickson et al. 1984), but the advantages accruing to otters from these associations are unknown.

In this study I examined the foraging behavior of free-ranging otters, comparing percent successful dives (dives resulting in prey capture), durations of dives, and durations of eating (an index of prey size) for otters hunting alone and those hunting in pairs to determine whether hunting in pairs affected individual foraging success.

Study Site and Methods

The study site encompassed 2 km of the Tomahawk River near its origin from Kawaguesaga Lake in northcentral Wisconsin. Maximum depth of the water along this part of the river was approximately 2 m. The section of river where otters foraged most often was 1 to 1.5 m deep and contained relatively abundant submerged vegetation. Most species of game and forage fishes common in northern Wisconsin (*Esox* sp., centrarchids, percids, catastomids, and cyprinids) were present in both the river and lake (Andrews and Threinen 1966).

I observed a group of otters varying in size from 1 to 6 animals ($\bar{x}$ = 3.2, sd = 1.8) from 1700 to 1820 CST (Central Standard Time) 5-7 times per week from 9 February to 3 April 1977, using binoculars from a distance of 30 to 50 m. The otters seemed to form a cohesive group. When two or more otters were present, they maintained close contact, usually staying within a few meters of each other. They moved from place to place as a group, remained near each other while foraging, and commonly engaged in affiliative social interactions such as social grooming and wrestling (Beckel 1982).

Because animals were unmarked and stayed very near each other while foraging, it was not possible to keep track of success rates, durations of dives, and durations of eating for more than two otters hunting together. Of the 36 observations when otters were present at the study site, there were 6 when only two otters were present and 10 when only one animal was there. Data on percent successful dives, durations of dives, and durations of eating were taken only from those observations when otters could be clearly observed and identified individually and were considered to be intent on hunting: 3 hunting bouts, which included 33 dives, for otters foraging alone; 5 bouts, which included 126 dives, for otters foraging in pairs.

Although otters occasionally caught and ate crayfish and frogs, they preyed primarily on fish. Analyses of durations of eating were limited to measurements made when otters were eating fish. Most of the fish caught by otters appeared to be sunfish types (Bluegills, *Lepomis macrochirus*, and Pumpkinseeds, *L. gibbosus*) and Yellow Perch (*Perca flavescens*), but identification of species was too uncertain to include these data.

All statistical tests are from Snedecor and Cochran (1967). Because the success rates, durations of dives, and durations of eating for two otters hunting together were similar for both otters during most observations, and because I could not be certain that I was seeing the same two otters during each observation when there were only two present, data for otters hunting together were pooled.

Results

Otters hunting in pairs remained within a few meters of each other while foraging, but they did not dive together nor did they appear to coordinate their hunting efforts. I observed no food sharing or fighting over food.

The average number of dives per otter per hunting bout was similar whether the animals were hunting singly or in pairs (Table 1). Otters hunting alone, however, had significantly greater success rates than otters hunting together (Chi-square = 9.1, df = 1, $p < 0.01$; Table 1).

There were no differences between the durations of dives of otters foraging alone and those of otters foraging in pairs (Mann-Whitney U = 638.5, $n_1 = 27$, $n_2 = 26$, $p \geq 0.05$), or between the durations of successful dives and unsuccessful dives (M-W U = 663, $n_1 = 26$, $n_2 = 27$, $p \geq 0.05$, otters hunting singly and in pairs combined, Table 1).

Because the time required to eat a fish is closely related to its length over a range of 7.5 to 20 cm (Beckel 1982), I could estimate the size of fish caught by otters. Most fish captured were small, generally 8-15 cm long, but it was not unusual for otters to catch fish 15-20 cm long. They rarely caught fish larger than 20 cm. Otters generally remained in the water to eat prey smaller than 15 cm and came out onto the surface of the ice or shore to eat larger fish. Measurements of duration of eating included only time spent eating the fish.

For otters foraging in pairs, the average time required to eat fish was greater than that for otters foraging alone (Table 1), suggesting that otters hunting together caught larger fish. However, the difference in durations of eating for animals hunting together and those hunting alone was not significant (M-W: U = 99, $n_1 = 8$, $n_2 = 19$, $p \geq 0.05$). Durations of successful dives were unrelated to durations of eating (length of fish caught) for otters foraging alone (Rho = 0.22, df = 17, $p \geq 0.05$) and for those foraging in pairs (Rho = -0.20, df = 6, $p \geq 0.05$), indicating that the length of a dive was not related to the size of fish caught.

Discussion

These results for *L. canadensis* contrast with those found by Kruuk and Hewson (1978) for the European Otter (*L. lutra*) foraging along the northwest coast of Scotland and by Conroy and Jenkins (1986) for *L. lutra* hunting along the coast of Shetland and in freshwater lochs in northeast Scotland. For *L. lutra,* which were always observed foraging singly, Kruuk and Hewson found considerably lower success rates (19.2%), than for otters in this study. Success rates for *L. lutra* foraging along the coast of Shetland (27.5%) and in freshwater lochs (7.1%) were also low (Conroy and Jenkins 1986).

TABLE 1. Success rates, durations of dives, and durations of eating for otters foraging alone and for two otters foraging together.

	Single Otters			Two Otters Foraging Together		
Number of foraging bouts	3			5		
Number of dives	33			126		
Average number of dives per otter per bout	11			12.6		
Number of successful dives	25			45		
Average number of successful dives per otter per bout	8.3			4.5		
Percent successful dives	$\bar{x}$ = 76% range 43%-100%			$\bar{x}$ = 36% range 16%-50%		
	$\bar{x}$ + sd	range	n	$\bar{x}$ + sd	range	n
Duration of dives (sec)	44 ± 13	22-68	27	45 ± 13	24-79	26
Duration of successful dives (sec)	45 ± 14	22-68	19	40 ± 9	31-59	8
Duration of unsuccessful dives (sec)	41 ± 17	22-56	8	48 ± 13	24-79	18
Duration of eating fish (sec)	15 ± 8	5-35	19	34 ± 32	5-84	8

Kruuk and Hewson also found that successful dives were significantly shorter ($\bar{x}$ = 15.9 sec) than unsuccessful dives ($\bar{x}$ = 24.8 sec), as did Conroy and Jenkins for otters foraging in a marine habitat (successful dives, ave. = 13.3 sec; unsuccessful dives, ave. = 22.7 sec). Conroy and Jenkins found no difference, however, in the durations of successful and unsuccessful dives for otters in freshwater lochs (successful dives, ave. = 13.1 sec; unsuccessful dives, ave. = 12.7 sec). In this study, *L. canadensis* dives were longer, and successful dives were no shorter than unsuccessful ones. These differences in success rates and dive durations could be related to differences in the abundance and availability of prey in different habitats or to species differences in hunting techniques or strategies.

Although interpretation of data from this study are limited by small sample size and the inability to identify individual otters from one observation to the next, it is somewhat paradoxical that otters usually remained very close to each other while foraging even though otters hunting alone had higher success rates. The animals appeared to be similar in size, but it may be that otters foraging alone were adults, whereas those foraging together were subadults or an adult with a subadult or large juvenile. It is also possible that the number of otters foraging in an area affects the behavior of prey or that otters use somewhat different foraging tactics when hunting alone or with another animal. For example, otters foraging in pairs did not appear to cooperate in prey capture, but they caught somewhat larger fish than those foraging alone.

Perhaps foraging in a group, where there may be increased awareness, affords some protection from having prey taken by eagles. I observed two instances when Bald Eagles (*Haliaeetus leucocephalus*) attempted to take fish from otters (Beckel 1981). On both occasions the otters were foraging together and the eagle was unsuccessful in obtaining the prey.

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A Bluegrass, *Poa pseudoabbreviata* Roshev., New to the Flora of Canada, and Some Additional Records from Alaska

WILLIAM J. CODY[1], STEPHEN J. DARBYSHIRE[1] and CATHERINE E. KENNEDY[2]

[1]Biosystematics Research Centre, Agriculture Canada, Ottawa, Ontario K1A 0C6
[2]Yukon Department of Renewable Resources, Box 2703, Whitehorse, Yukon Y1A 2C6

Cody, William J., Stephen J. Darbyshire and Catherine E. Kennedy. 1990. A bluegrass, *Poa pseudoabbreviata* Roshev., new to the flora of Canada, and some additional records from Alaska. Canadian Field-Naturalist 104(4): 589–591.

A bluegrass, *Poa pseudoabbreviata*, is added to the list of rare species for Canada and the Yukon Territory and new records are reported for the state of Alaska. Problems relating to the scientific name are discussed. A short description of the species is provided.

Key Words: Bluegrass, *Poa pseudoabbreviata*, rare plants, Canada, Yukon Territory, Alaska.

During an ecological survey of Northern Yukon National Park in 1988, a specimen of a small grass was collected that proved after careful examination, to be *Poa pseudoabbreviata* Roshev. A second collection was made in 1989 from about 50 km to the northwest. Data for these collections are: YUKON, Northern Yukon National Park, British Mountains: Headwaters of Bear Creek, NW of Trail Creek, 68°51′N 139°52′W, elevation 1170 m, residual blockfield of non-glaciated crest, slope 3%, *C. E. Kennedy 83*, 24 July 1988 (DAO 574090) (Figure 1); and Malcolm River, 69°20′N 140°12′W, lichen talus mountain summit, *C. E. Kennedy 89-34*, 23 July 1989 (DAO 583135).

Poa pseudoabbreviata is reported for the first time in the flora of Canada and should be added to the lists of rare plants for Canada (Argus and Pryer 1986) and the Yukon Territory (Douglas et al. 1981).

Hultén (1973), after examining the type of *P. pseudoabbreviata* accepted the view of Tzvelev (1964), that *P. brachyanthera* Hultén is a synonym. He stated that the Asiatic range of *Poa* species 38, *P. pseudoabbreviata*, in his Alaskan flora (Hultén 1968), should apply to species 36 (*P. brachyanthera* now treated as *P. pseudoabbreviata*) and that the North American range of species 38 should be referred to *P. abbreviata* R.Br. ssp. *jordalii* (Porsild) Hultén.

Recent acquisitions to the Vascular Plant Herbarium, Biosystematics Research Centre (DAO) and an examination of specimens at the National Herbarium, Canadian Museum of Nature (CAN) demonstrated that *Poa pseudoabbreviata* occurs well outside the Alaskan range given by Hultén (1968).

The species is now known throughout the Brooks Range from Ogotoruk Creek, 165°46′W longitude to Okpilak Lake, 143°59′W longitude, indicating the continuous distribution between the collections plotted by Hultén (1968) from the Chukot Peninsula and the Yukon specimens cited above. Additional sites are also known in southern Alaska. Of particular interest is a collection from Juneau Icefield in the northern Panhandle. This latter collection would suggest that the species should be searched for in Kluane National Park in southwestern Yukon Territory.

Specimens examined from Alaska are: Popof Island, Shumagin Island, *T. Kimcaird s.n.*, 8-19.VII.1899 (CAN 274878) [*Poa brachyanthera* Hultén type fragment]; Mt. McKinley Park, *A. & R. Nelson 4311*, 3.VIII. 1939 (CAN 274864); west of Lake Schrader, 69°25′N 145°0′W, *L. A. Spetzman 1427*, 10.VII.1948 (CAN 211085); Okpilak Lake, 69°24′N 144°04′W: barrens, quartzite, windswept ridge, elev. 5200 ft., *J. E. Cantlon & W. T. Gillis 57-1833*, 5.VII.1957 (CAN 274871); tussock meadow, elev. 4800 ft., *J. E. Cantlon & W. T. Gillis 57-1826*, 5.VIII. 1957 (CAN 274869); 5 miles southeast of Okpilak Lake 69°23′N 143°59′W: frost boils of raw silt, quartzite flats, elev. 4700 ft., *J. E. Cantlon & W. M. Malcolm 58-0356*, 23.VII.1958, (CAN 274870); small benches, limestone-quartzite contact, south-facing slope, elev. 5200 ft., *J.E. Cantlon & W. M. Malcolm 58-0329*, 23.VII.1958 (CAN 274866); East Fork of the Kuskokwin River, 62°40′N 152°30′W, loose talus on a steep south-facing slope, *L. A. Viereck 5007*, 15.VII.1961 (CAN 362110); Liberator Lake 68°52′N 158°20′W, *K.Holmen & O. Martensson 61-1701*, 19-25.VII.1961 (CAN 271112); Ogotoruk Creek, 68°06′N 165°46′W, northwest-facing slopes, sandstone, elev. 100-500 ft., *J. G. Packer 2163,* 17.VII.1962 (DAO 143379); Kukpuk River, low sandstone-siltstone fellfield ridge, *H. R. Melchior 526*, 8.VII.1963 (CAN 283914); Juneau Icefield, rock ledges, elev. 1430 m, *R. Beschel 15509A*, 11.VIII.66 (DAO 607153); Atigun Pass, 68°08′N 149°30′W, alpine tundra slope, elev. 1200-1300 m, *D. F. Murray & A. W. Johnson 6239*, 26.VII.1976 (CAN 454482); Galbraith Lake, 68°30′N 149°25′W, tundra slopes and conglomerate outcrops, wet site

FIGURE 1. Specimen of *Poa pseudoabbreviata* from Northern Yukon National Park (*C. E. Kennedy 83* DAO).

in protection of boulder, elev. 915-1400 m, *D. F. Murray & A. W. Johnson 6467*, 22.VII.1977 (DAO 239147); Kigalik Test Well, headwaters of Pahron Creek, 69°28'N 157°20'W, fellfield, elev. 300 m, *D. F. Murray 6858*, 25.VII.1978 (DAO 238654).

A map of the amphi-Beringian distribution of *P. pseudoabbreviata* based on Hultén (1968), Probatova (1985) and Tzvelev (1964) together with the new sites in northern Yukon Territory and Alaska is presented in Figure 2.

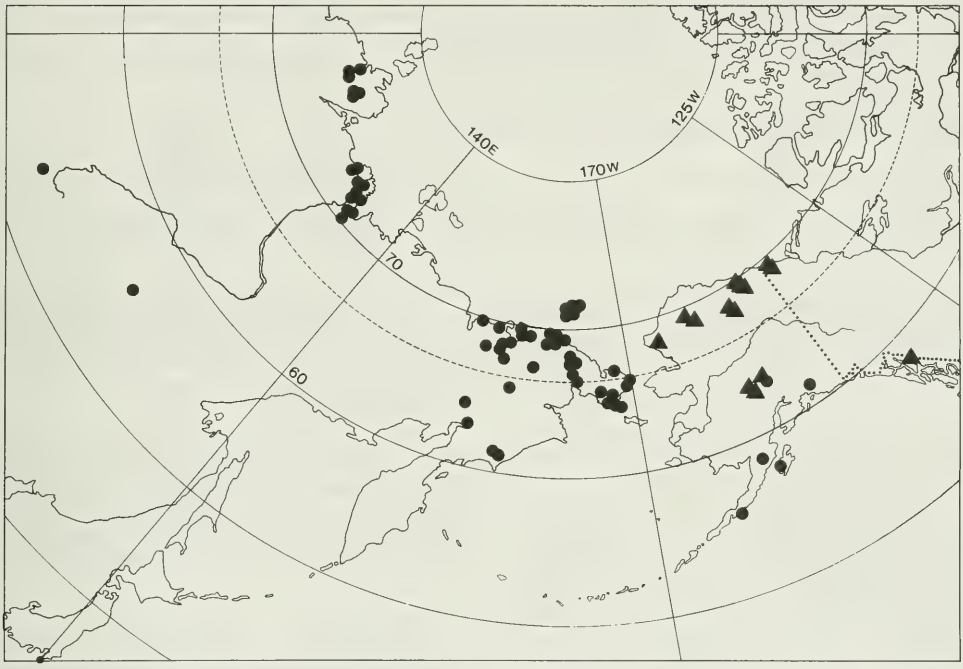

FIGURE 2. Amphi-Beringian distribution of *Poa pseudoabbreviata* based on Hultén (1968), Probatova (1985) and Tzvelev (1964) (●) with new localities in northern Yukon Territory and northwestern Alaska (▲).

Poa pseudoabbreviata is a loosely tufted plant with culms 5 to 20 cm in height, well above a basal tuft of short and narrow leaves; the panicle is ovate with its branches long, slender, and usually lax and glabrous; the glumes are glabrous; the lemmas are glabrous between the basally puberulent keel and marginal nerves; the anthers measure 0.3 to 0.5 mm long. There is no webby tuft on the lemma callus. It is reported from rocky slopes and snow beds in Alaska (Hultén 1968) and stony tundras and bald mountain peaks in the far eastern USSR (Tzvelev 1976).

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Reactions of Grizzly Bears, *Ursus arctos horribilis*, to Wildfire in Yellowstone National Park, Wyoming

BONNIE M. BLANCHARD and RICHARD R. KNIGHT

Interagency Grizzly Bear Study Team, Forestry Sciences Lab, Montana State University, Bozeman, Montana 59717

Blanchard, Bonnie, M., and Richard R. Knight. 1990. Reactions of Grizzly Bears, *Ursus arctos horribilis*, to wildfire in Yellowstone National Park, Wyoming. Canadian Field-Naturalist 104(4): 592–594.

Twenty-one radio-monitored Grizzly Bears (*Ursus arctos horribilis*) within the Yellowstone ecosystem had annual ranges encompassing all or portions of the 1988 wildfires. The most important immediate effect of the fires on Grizzly Bears was the increased availability of ungulate carcasses during a fall otherwise offering few foraging opportunities. The fires had no apparent effects on overall choice of den sites, annual range sizes, or mean rates of movement.

Key Words: Grizzly Bear, *Ursus arctos horribilis*, Yellowstone National Park, wildfire, food habits.

Heavy fuel accumulations and unprecedented climatic conditions during the summer of 1988 caused fires in the Yellowstone ecosystem to burn portions of over 562 000 ha (Schullery 1990). Record drought, high temperatures, low humidity, and high velocity winds created conditions allowing live embers to be carried as much as 2.5 km in advance of the fire front; fires advanced as much as 16 km in one day. These record-breaking fires affected not only the vegetation, but also the resident animal populations.

Grizzly Bears within the area have been monitored through the use of radio-telemetry since 1975 as part of the Interagency Grizzly Bear Study to determine the status and trend of the population. During 1988, 38 Grizzly Bears were wearing active transmitters within the Yellowstone ecosystem when the fire season began. Bears monitored during and after fires were originally captured and instrumented to gather data for research objectives other than response to fire.

Instrumented bears were routinely located once or twice a week prior to fire suppression efforts. Heavy smoke and air traffic restrictions from the first week of August to late September defeated efforts to routinely locate bears within active fires, however all monitored bears were located at least every four weeks. The majority of data are limited to responses of bears after the passing of a fire. Limited additional data were gathered within active burns through ground monitoring of individuals and high altitude telemetry locations from aircraft above the smoke layer. Analyses of movements in reaction to fire were further confounded by the extreme drought conditions which alone normally precipitate movements of bears (Knight et al. 1984).

Details of methodology for capturing, instrumenting, and radio-tracking have been described (Blanchard 1985). Annual range sizes were estimated by the minimum convex polygon (MCP) method (Stickle 1954), and mean rates of movement (MRM) were calculated from harmonic mean distances between successive locations. Biomass of available carcasses was calculated from approximate average live weights given by Murie (1951), and approximate percentage consumed was estimated by experienced field personnel.

Results

Twenty-one of the 38 radio-monitored bears had home ranges containing one or more of the 1988 fires. Thirteen of the 21 bears moved into burned areas after the fire front passed, three remained within active burns as the fire progressed, three stayed outside burn lines at all times, and two could not be located after the fires. Average annual range sizes of six individuals were larger during 1988 compared to previous years, although the difference was not statistically significant (paired t, $P = 0.163$). Five adult females had average annual ranges of 162 km^2 prior to 1988 compared to 191 km^2 in 1988, while one adult male had an annual range of 450 km^2 during 1988 compared to 239 km^2 in previous years. The fires had no apparent overall effect on seasonal mean rates of movement (MRM) (paired t, $P > 0.140$). Average summer (1 July-31 August) MRM for three adult females was 0.590 km/day during 1988 compared to 1.051 km/day during previous years, while average fall (1 September-30 November) MRM was 0.878 km/day during 1988 compared to 0.606 km/day during previous years.

Movements During Active Fires

The three Grizzly Bears which remained within actively burning areas were adult females with no young. Two additional adult females may have succumbed to the fires as they could not be found after fire storms passed rapidly through drainages they had been using consistently that summer. Neither was located after the fires despite extensive aerial searches. Both were wearing transmitters with at least two more years life expectancy, and neither bear was recaptured at its original trap site during 1989 despite concerted efforts.

TABLE 1. Comparison of volume and frequency of ungulates in Grizzly Bear scats collected during 1979-1987 and 1988.

	Sample size		% Volume		% Frequency	
	Study	1988	Study	1988	Study	1988
August	787	58	2.9	5.2	4.2	8.6
September	499	55	4.7	18.1	4.8	29.1
October	340	7	7.7	28.6	8.5	28.6

Movements After Active Fires

Over half (13) of the 21 bears moved into burned areas after the fire front had passed. They were often located within still smoldering or slowly advancing fires. Ground investigations of aerial locations revealed these bears foraged in burned sites — feeding on carcasses of ungulates killed in the fires, grazing on newly emerged *Carex* and *Poa* species, digging in logs and anthills for insects, and excavating tubers and corms in nonforest surface burns. Six of the 13 which moved into burned areas were located east of the park in the Jones Creek drainage of the North Fork of the Shoshone River, where 100-500 ungulates were estimated to have perished during the fire (S. Benson, State Game and Fish Department, Cody, Wyoming; personal communication). The degree to which a carcass was consumed by bears depended on the extent of charring and the abundance of other carcasses. Hard exteriors of badly charred carcasses appeared to prevent extensive use. Based on conclusions drawn from observations of carcasses, bears consumed only small amounts of any one carcass when many were available, moving often from carcass to carcass and seldom burying any for later consumption.

A group of 146 Elk (*Cervus elaphus*) carcasses was found clustered within a burned drainage approximately 25 days after the fire had passed through. Thirty-five carcasses had been fed on by both Black Bears (*Ursus americanus*) and Grizzly Bears; however, only four had been buried, and an average of approximately 13% of the available biomass had been consumed by all scavengers including bears, Coyotes (*Canis latrans*), and Ravens (*Corvus corax*) (S. French, Yellowstone Grizzly Foundation, Evanston, Wyoming; personal communication). No radio-marked Grizzly Bears were known to use these carcasses. However, during a six-day period, four to six different Grizzly Bears and one Black Bear were located at or near the carcasses by use of tracks and observations.

Scat content during and after the fires substantiated a greater than normal consumption of ungulates during late summer and fall. Ungulates usually constituted three to eight percent of the annual scat volume from August-October (Mattson et al., *in press*); however, in 1988 the volume was significantly greater (paired t, P = -0.076) (Table 1).

Fires had no apparent effect on choice of den sites. Sites were located for 13 bears after the fires. Five denned within burned areas and eight outside. Den sites from previous years were known for 10 of the 13 bears. Four of the eight bears that denned outside burns in 1988 had previously denned outside the 1988 fire line, whereas the other four had denned inside the 1988 fire line. Two bears that denned inside burned areas in 1988 had also denned inside the fire line during previous years.

Discussion

The most important apparent immediate effect of fires on Grizzly Bears was the increased availability of some food items, especially carcasses of Elk. These appeared to be the main attractant bringing bears into burned areas. The drought, combined with low Whitebark Pine (*Pinus albicaulis*) seed production in 1988, portended bleak fall foraging opportunities for Grizzly Bears. A significant negative correlation has been documented between level of cone production and numbers of Grizzly Bears trapped in management actions after 1 August (Blanchard 1990). In fact, many bears were already seeking alternate foods associated with human activities by July. At least 11 grizzlies were observed by residents near home sites and campgrounds east of the park in Sunlight Basin, Wyoming, alone, during July and August (F. Hammond, State Game and Fish Department, Cody, Wyoming; personal communication). Throughout the entire study area, 18 Grizzly Bears were captured in management actions between 1 August and 1 October, compared to an annual average during 1980-1987 of 13 (monitoring of bears captured during management actions began in 1980). The majority of bear-related management actions had ceased by October as bears were drawn into burns seeking carcasses, and only one Grizzly Bear was captured as a result of management actions after 1 October in comparison to the annual average of six during years of low fall food availability.

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A Comparison of the Efficacy of Two Types of Live Traps for Capturing Muskrats, *Ondatra zibethicus*

MICHAEL J. LACKI[1], WILLIAM T. PENESTON[2], and F. DANIEL VOGT[2]

[1]Department of Forestry, University of Kentucky, Lexington, Kentucky 40546-0073
[2]Department of Biological Sciences, State University College, Plattsburgh, New York 12901

Lacki, Michael J., William T. Peneston, and F. Daniel Vogt. 1990. A comparison of the efficacy of two types of live traps for capturing Muskrats, *Ondatra zibethicus*. Canadian Field-Naturalist 104(4): 594–596.

The efficacy of double-door Havahart and Tomahawk live traps to capture Muskrats (*Ondatra zibethicus*) was studied in three sites in Clinton County, New York, from June through August, 1986. Adult ($P < 0.01$) and juvenile ($P < 0.05$) Muskrats were captured more frequently in significantly greater numbers with Tomahawk than Havahart traps. Recapture rates were lower for juveniles than for adults and were then trap-dependent, with lower recapture rates for Havahart than Tomahawk traps.

Key Words: Capture rate, live traps, age ratios, Muskrats, *Ondatra zibethicus*.

Selection of trap type for use in studying rodent populations must consider the efficiency of the trap in capturing the species studied, and individuals of different ages, and sexes in proportion to their availability. Variation in capture success of small rodents (< 300 g) has been demonstrated for Longworth traps (Grant 1970; Boonstra and Krebs 1978; Boonstra and Rodd 1982), between old and new model snap traps (West 1985), and among pitfall, snap traps and Sherman live traps (Williams and Braun 1983). Comparisons of the effectiveness of commercially available live traps for sampling larger rodents (> 300 g) have not been made. However, Parker and Maxwell (1980) suggested that the Tomahawk trap was superior to the Havahart trap when trapping Muskrats, and earlier studies by Takos (1943) and Aldous (1946) also suggested differential success at capturing Muskrats, but in all cases no data were provided. We tested and compared the success of Havahart (Woodstream Corp., Lititz, Pennsylvania) and Tomahawk (Tomahawk Live Trap Co., Tomahawk, Wisconsin) live traps for capturing Muskrats (*Ondatra zibethicus*) of different sex and age categories.

Havahart (18.5 × 18.5 × 62.5 cm) and Tomahawk (16.5 × 16.5 × 61.5 cm) live traps with two doors, one at each end, were set at 3 sites from 3 June to 22 August, 1986. Two sites were located along the Little Chazy River, Clinton County, New York (44°51′N; 73°35′W) on the William H. Miner Institute Estate. These sites were created by water back flows from a series of dams along the river, but had a steady and noticeable movement of water through the emergent vegetation. Water levels at these sites fluctuated slightly (< 10 cm) during trapping. The dominant emergent vegetation was

TABLE 1. Total captures of Muskrats with Havahart and Tomahawk live traps, from June to August 1986. Number of individual Muskrats captured are in parentheses.

Trap type	Trap nights	Adults			
		Males	Females	Juveniles	Combined
Havahart	515	0	0	16(14)	16
Tomahawk	583	11(8)	15(9)	34(28)	60

sedges (*Carex* spp.) and Burreed (*Sparganium eurycarpum*). The third trap site was a fen at the south inlet of Upper Chateaugay Lake, Clinton County, New York (44°42′N: 73°35′W). The south inlet was subject to greater water level fluctuation (20.5 cm) than the other sites, with the change being due primarily to a steady decline in water level thoughout the summer. Cattail (*Typha latifolia*) was the dominant emergent plant species. Surface water movement was not evident in the trapping area at the fen.

Bait was not used in the traps because food items and artificial lures may vary in their ability to attract individuals of different age and sex classes and could confound the design of our experiment. Traps were set deliberately in travel lanes and at other points of high Muskrat activity to improve capture success, as a grid placement approach during the previous summer proved inefficient. Both trap types were distributed throughout each locality and among all signs of Muskrat activity equally to avoid bias due to trap placement. Traps were set between 1100 and 1400 hours and sprung the following day between 0800 and 1100 hours. On a particular night, traps were opened either at the William H. Miner Institute or the south inlet, but never at both locations simultaneously. Trapping was conducted on 31 nights for a total of 1098 trap nights. Thirty-three Havahart and 39 Tomahawk traps were used during the study. Each animal was tagged with two numbered, metal ear tags. Prior to release, each animal was weighed, aged and sexed according to the methods of Baumgartner and Bellrose (1943).

Trap success was evaluated using the Z statistic, test for two proportions (Dunn 1964). Data for adults and juveniles were analyzed separately, with capture frequencies adjusted to account for traps rendered unavailable due to the capture of individuals from the other age class. Sexes were combined for analysis. Tests of trap success were based on all animals captured, including recaptures.

Our overall capture rate was 1 Muskrat/14.4 trap nights. Capture success of the two types of traps were significantly different. Tomahawk traps captured both adult ($Z = 4.90$, $P < 0.01$) and juvenile ($Z = 2.31$, $P < 0.05$) Muskrats in greater numbers and higher frequencies than did Havahart traps (Table 1; Figure 1), thus rejecting the null hypothesis that both trap types are equally successful at capturing Muskrats. No adult Muskrats were captured with Havahart traps. Rates of recapture with Tomahawk traps, scaled against all individuals captured at least once in an age class, were lower for juveniles (14.3%) than adults (41.2%). The recapture rate of juveniles with Havahart traps was even lower (4.8%), reflecting the overall poor performance of this trap type. The low juvenile recapture rates were probably due in part to juveniles being transient, contrary to adults which tend to be territorial (Errington 1961). Parker and Maxwell (1980) found that capture success improved after switching from Havahart to Tomahawk live traps during a spring trapping season. However, this improved trap success may have been due to seasonal increases in Muskrat activity or increased Muskrat density from spring litters.

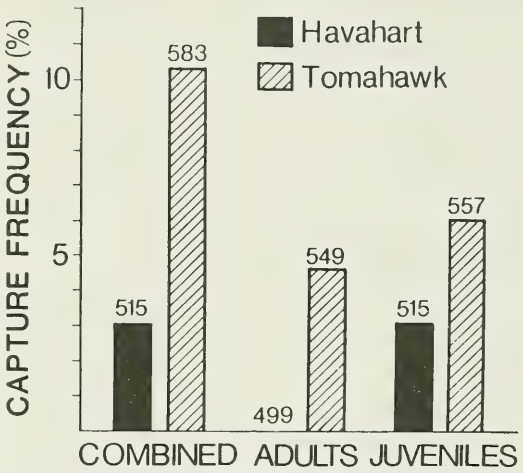

FIGURE 1. Frequency of capture of adult and juvenile Muskrats with Havahart and Tomahawk live traps, from June to August 1986. The number above each bar represents the number of trap nights.

The difference in performance of the two types of traps may be due to the triggering mechanism. Boonstra and Rodd (1982) demonstrated that Longworth live traps were less efficient at capturing large Meadow Voles (*Microtus pennsylvanicus*) than smaller individuals in the same population.

Longworth traps operate on a gravity drop-door system as do Havahart traps, whereas Tomahawk traps operate by a spring-loaded door system. Boonstra and Rodd (1982) attributed the large number of empty, sprung traps to larger animals that were able to back out. The difference in trap success that we observed for adult muskrats may indicate a similar trap response, as Havahart traps were often found sprung and empty. This would not explain the different capture success for juveniles, though, unless Havahart traps were more prone to malfunction due to other factors such as wind and rain. We have no data to confirm or refute this possibility. These data indicate that choice of live trap impacts studies examining age ratios of Muskrats, as within population ratios are substantially dependent on the type of live trap selected.

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"Blond" Color Morph of Meadow Voles, *Microtus pennsylvanicus*, from Massachusetts

DENVER W. HOLT

The Owl Research Institute, P.O. Box 8335, Missoula, Montana 59807

Holt, Denver W. 1990. "Blond" color morph of Meadow Voles, *Microtus pennsylvanicus*, from Massachusetts. Canadian Field-Naturalist 104(4): 596–597.

"Blond" color morphs of Meadow Voles were discovered on a Massachusetts island in conjunction with Short-eared Owl research. This is the only island in eastern North America where this color morph has been found to date.

Key Words: Meadow Vole, *Microtus pennsylvanicus*, blond morph, island.

The pelage in the genus *Microtus* varies from pale yellow to dark brown or black because of differences in the width of the subapical band of yellow pigment on black hairs, and the total number of completely black hairs (Gaines 1985). Variation in the pelage color of *Microtus pennsylvanicus* has been reported (Gaines 1985: 847-848, Table 1).

I analyzed Short-eared Owl (*Asio flammeus*) pellets collected on Monomoy National Wildlife Refuge (41° 38′ N, 60° 58′ W), from 1982-1987. Monomoy is an island off the "elbow" of Cape Cod, Chatham, Massachusetts. Because of Monomoy's location, it is subject to dramatic erosion and deposition and continuously changes configuration. It cur-

rently consists of two islands, North and South Monomoy.

I collected and identified 3243 Short-eared Owl pellets, using the methods described by Holt et al. (1987), from the Monomoy Islands. Within these pellets, I recorded 2992 *M. pennsylvanicus* skulls. If a pellet was composed of "blond" fur and had one *M. pennsylvanicus* skull in it, I considered it to be composed of a "blond" vole. Of the 2992 voles recorded, eleven or 1 in 272 were "blond", representing 0.37% of the total. An additional 1235 *M. pennsylvanicus* skulls were recorded from Short-eared Owl pellets from several other areas of Cape Cod and its islands, but no other "blond" voles were recorded.

"Blond" voles on Monomoy have been observed infrequently (D. Holt and R. Humphrey, personal observation). One specimen collected by R. Humphrey and additional hairs were deposited at the Biology Department Museum at Northeastern University, Boston, Massachusetts. The specimen was described as "blond" with dark eyes.

Clark (1938) and Owen and Shackelford (1942) reported *M. pennsylvanicus* that included "cream" and "yellow" individuals, respectively. Clark (1938) received 14 "cream" colored *M. pennsylvanicus* from Blue Earth, Minnesota. Two of these were mated in laboratory experiments and produced 12 "cream" colored voles of 63 born. Clark (1938) concluded that "cream" color depends on a single recessive gene. Owen and Shackelford (1942) examined hairs of "yellow" voles and reported them to be agouti (containing two pigments; yellow and black), and that a typical hair is black except for the subapical band of yellow. Though yellow granules existed throughout the hair, they were masked by larger black strands in the cortex and medulla, resulting in a basically black hair; however, in the subapical band, no black granules existed (Owen and Shackelford 1942). Though "cream" and "yellow" color variations in *M. pennsylvanicus* have been reported from few areas (Clark and Shackelford 1942, Table 1), only one "yellow" specimen has been reported from Massachusetts, a specimen dated 1860 from the interior portion of the state (Owen and Shackelford 1942).

Gaines (1985) pointed out that the older literature is often confusing because no cross checks were made of phenotypes previously described and the same color morphs may have been renamed a new color based on personal interpretation. I matched the dry hairs of one "blond" vole collected by R. Humphrey with the Munsell Color Charts (1975). I found the color to range from "very pale yellow" (Code 10 YR 8/3 — dry) for single strands of hair to "brownish yellow" (Code 10 YR 6/6 — dry) for the overall pelage color.

It is important that one should compare aberrantly colored specimens with museum collections and color standard charts such as Munsell's (1975) to reduce confusion about phenotypes when describing new color morphs. Further, laboratory breeding data are needed to determine the genetic make-up and manner of inheritance of such aberrant color morphs. This may help in evaluating the possible selective pressures involved in determining the phenotype, and its overall contribution to a vole's fitness.

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Parturition in the Silver-haired Bat, *Lasionycteris noctivagans*, with a Description of the Neonates

ALLEN KURTA[1] and MARY E. STEWART[2]

[1]Department of Biology, Eastern Michigan University, Ypsilanti, Michigan 48197
[2]Office of the Vice President for Research, University of Michigan, Ann Arbor, Michigan 48109

Kurta, Allen, and Mary E. Stewart. 1990. Parturition in the Silver-haired Bat, *Lasionycteris noctivagans*, with a description of the neonates. Canadian Field-Naturalist 104(4): 598–600.

A female Silver-haired Bat (*Lasionycteris noctivagans*) was mist-netted 3.2 km E of Vermontville, Eaton Co., Michigan, on 18 June 1979, and held in a wire-mesh cage. On 20 June it gave birth to a female and a male between 1602 and 1646 h. The mother was 102.0 mm in total length and weighed 11.0 g. The female young measured 44.7 mm, and the male 47.1 mm; each weighed 2.5 g including the placenta. Birth process and consumption of placenta by the mother were noted as was the deciduous tooth formula; the latter was similar to other vespertilionid genera.

Key Words: Silver-haired Bat, *Lasionycteris noctivagans,* parturition, neonates, Michigan.

The Silver-haired Bat (*Lasionycteris noctivagans*) [Chiroptera: Vespertilionidae] is a tree-dwelling species that ranges across much of North America. The species is monotypic and the only member of the genus. Because it is generally solitary in nature (Kunz 1982; but see Parsons et al. 1986), there is little information concerning parturition in *L. noctivagans*, other than a brief description of a single neonate and a stillborn infant (Kunz 1971). Herein we 1) provide a detailed description of the birth process, 2) report maternal consumption of the placenta, 3) describe the morphological and behavioural condition of two neonates, and 4) document the deciduous tooth formula. These observations significantly add to our knowledge of *L. noctivagans* and provide valuable information on the details of parturition in polytocous bats (i.e., those with litter size > 1). Less than 10% of all bats are polytocous, and most knowledge of parturition in these species is limited to simple descriptions of the neonates (Kurta and Kunz 1987; Wimsatt 1960).

On 18 June 1979, at 2145 hours (Eastern Daylight Time), a female *L. noctivagans* was mist-netted 5 m above the Thornapple River, 3.2 km E of Vermontville, Eaton Co., Michigan. The obviously pregnant animal was confined in a wire-mesh cage beginning at 0300 hours on 19 June. On 20 June, at approximately 1530 hours, the animal became restless, wandered about the cage, and occasionally emitted audible squeaks. At 1602 hours, she assumed a head-up (45° angle) position on the side of the cage with her interfemoral membrane curled ventrally and upward to form a basket. The first neonate began to exit the birth canal at this time. The birth was breech with the right hind leg and tail vertebrae appearing first; the young bat was not encased in the amnion which must have ruptured early in the parturition process. Once the hindquarters were free, the newborn, a female, actively helped in the birth process by pushing against the mother with her hind legs while the neonate's head and shoulders were still within the birth canal. The mother constantly licked the emerging young. Birth was completed in 23 min at 1625 hours. After birth, the mother continued to lick her offspring, often in apparent response to its high-pitched chirps. The newborn female quickly found her way to the mother's left nipple. The umbilical cord was still intact, and the placenta had not been discharged.

The second neonate, a male, began to emerge at 1630 hours. The birth was breech with posterior tail vertebrae and hind limbs emerging first; again, the amnion was already ruptured. The male did not push against the mother and seemed less active and less vocal than his sibling despite frequent licking by the mother. During the second birth, the mother assumed a position on the side of the cage with her head parallel to the cage floor or at a 45° angle with the head pointing up. The interfemoral membrane was curled as before. The second birth was completed at 1646 hours after only 16 min. Individual births of the polytocous *Nycticeius humeralis* required 3-114 min (Jones 1967). Elapsed time between the birth of the first and second *L. noctivagans* was 21 min. Orr (1954) reported 12-65 min between the births of twin *Antrozous pallidus*, and Sherman (1930) recorded approximately 15-45 min for twin *Myotis austroriparius*. The moderate duration of each birth in *L. noctivagans* (16 and 23 min) and the moderate interbirth interval (21 min) suggested a normal, not stress-induced, birth process (Wimsatt 1960).

The mother did not sever either umbilical cord, although she did gently bite the cords on a number of occasions during and after parturition. The right forearm of the male became entangled with his umbilical cord after birth, and this prevented him from reaching a nipple. In his attempts, the male

severely stretched the umbilical cord, as evidenced by a thinning of the cord and by obvious distention of the skin in the abdominal area. The cord of the male still appeared red in color, suggesting continued blood flow, as late as 1719 hours or 33 min after birth; apparently parturition itself is not the immediate stimulus for cessation of umbilical circulation. Wimsatt (1960) noted a similar elasticity to the umbilical cord of the monotocous *M. lucifugus* and reported that umbilical blood flow continued up to 10 min after birth. Bogan (1972) described continued blood flow for more than 50 min following birth in the polytocous *Lasiurus cinereus*.

At 1754 hours, the mother walked across the cage floor with the female neonate firmly attached to the adult's fur and nipple. The male, however, was pulled along by his intact umbilical cord, and the resulting tension may have helped draw the placenta out of the mother at this time. The placenta of the female neonate was expelled, apparently by uterine contractions, at 1807 hours; the mother immediately consumed part of the afterbirth of the female. Elapsed time between their respective births and delivery of the placenta was 69 min for the male and 102 min for the female. Sherman (1930) reported an elapsed time of 2-360 min in *M. austroriparius* after giving birth to twins. Bogan (1972) recorded 90 min for placental delivery in *L. cinereus*. In seven species of monotocous bats, the time between parturition and expulsion of the placenta varied between 30 and 570 min (Wimsatt 1960). The moderately short time required for expulsion of the placentae in our *L. noctivagans* (69 and 102 min) was additional evidence that the observed birth was normal and not stress-induced (Wimsatt 1960).

Shortly after delivery of the second placenta, we examined the bats. The neonates were capable of actively crawling across the cage or up its walls and could hang unaided in a vertical position. The female neonate exuded a small drop of urine when first picked up indicating some renal functioning. The bodies were generally pinkish in color, although the wings were mottled with tan and black. The eyes were closed. Although the black pinnae were folded at birth, one ear of the female neonate was erect by this time (1819 hours). The tragus also was erect. Light hair was apparent only about the lips. Both neonates frequently emitted high-pitched chirps after separation from their mother. Norris-Elye (1951) noted similar sounds from newborn *L. noctivagans* in the wild. These vocalizations are presumably analogous to the "isolation" calls of other bats (Gould 1971).

Total length of the female neonate was 44.7 mm; the male, 47.1 mm; and the mother, 102.0 mm. The mother weighed 11.0 g, and the neonates (plus placentae) weighed 2.5 g each. In the slightly larger vespertilionid *Eptesicus fuscus* (maternal mass = 16 g), placentae weighed 0.5 g (Stack 1985). Our newborn *L. noctivagans*, therefore, probably weighed at least 2.0 g without their placentae, or at least 18% of the mother's postpartum mass. Kunz (1971) described neonatal *L. noctivagans* weighing 1.8 and 1.9 g. Based on allometric relationships (Kurta and Kunz 1987), the predicted neonatal body mass for an 11-gram, polytocous vespertilionid was 1.9 g. The forearm length of the mother *L. noctivagans* was 40.0 mm; those of the juveniles were 14.2 and 14.0 mm for the female and male, respectively. The predicted neonatal forearm length was 13.5 mm (Kurta and Kunz 1987). The neonate examined by Kunz (1971) had a forearm length of 12.5 mm. The larger size of our bats compared to those of Kunz (1971) and the fact that our bats were slightly larger than predicted from allometric equations (Kurta and Kunz 1987) suggested that our bats were fully developed and not premature.

After returning the bats to their cage, we made only intermittent observations. The juvenile male died that evening; to our knowledge, he never attached to a nipple and presumably died from a lack of nutrition and/or water. The placenta of the male disappeared between 1823 and 1920 hours, apparently eaten by the mother. At 1945 hours while nursing the surviving neonate, the mother finished consuming the female's afterbirth. The second neonate lived until 23 June. The mother had refused food after the births and presumably was not producing an adequate milk supply.

After death, we examined the deciduous dentition using a 10x binocular microscope. The formula for the male's dentition was: incisors 2-2/1-1, canines 1-1/1-1, premolars 1-0/1-1. That of the female was: incisors 2-2/3-3, canines 1-1/1-1, premolars 1-2/2-2. A fourth upper premolar, however, was visible through the transluscent gum tissue of the female. Apparently the complete deciduous formula is: incisors 2-2/3-3, canines 1-1/1-1, premolars 2-2/2-2 (total = 22). This formula is the same as in other vespertilionid genera (Vaughan 1970; Funakoshi and Uchida 1981).

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New Records for the Alberta Flora: *Geranium pratense*, Meadow Crane's-bill, and *Anemone canadensis* f. *dicksonii*, a Canada Anemone Form

WILLIAM J. CODY[1] and GEORGE W. SCOTTER[2]

[1]Biosystematics Research Centre, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6.
[2]Canadian Wildlife Service, Environment Canada, 2nd floor, 4999-98 Ave., Edmonton, Alberta T6B 2X3

Cody, William J., and George W. Scotter. 1990. New records for the Alberta flora: *Geranium pratense*, Meadow Crane's-bill, and *Anemone canadensis* f. *dicksonii*, a Canada Anemone form. Canadian Field-Naturalist 104(4): 600–602.

Geranium pratense, Meadow Crane's-bill, is reported as new to the flora of Alberta and appears to be the first of a naturalized occurrence in the Prairie Provinces. The report of *Anemone canadensis* f. *dicksonii*, a Canada Anemone form is the second for Alberta, and the first since its original description.

Key Words: *Geranium pratense*, Meadow Crane's-bill, *Anemone canadensis* f. *dicksonii*, Canada Anemone, Alberta.

In the course of botanical observations in the vicinity of Edmonton, Alberta, GWS discovered two plants of particular interest. These are *Geranium pratense* L., Meadow Crane's-bill, and *Anemone canadensis* L. F. *dicksonii* Boivin, a double-flowered form of Canada Anemone.

Data are as follows:
Geranium pratense — Alberta, Edmonton, in a Canadian National railway parking lot and boulevard north of the railway tracks, 101 Street at 105 Avenue, *G. W. Scotter 88,101*, 23 July 1989 (DAO) and *88,105*, 16 August 1989 (DAO).

Anemone canadensis f. *dicksonii* Alberta, east side of Lily Lake, northeast of Edmonton (53°56′55″, 113°22′30″), *G. W. Scotter 88,102*, 23 July 1989 (DAO).

Geranium pratense (Figure 1) is new to the flora of Alberta, and indeed, the Prairie Provinces. It is a species which has become naturalized particularly in eastern North America. Fernald (1950) in Gray's Manual says "Fields and roadsides, Lab., Nfld. and Que. to N.S. and Me., rarely Mass. and N.Y." Scoggan (1957) reported *G. pratense* from Winnipeg, Manitoba, however Boivin (1972) stated that the label of the specimen collected by J. F. Higham in 1920 bears the acronym M.A.C., an abbreviation for Manitoba Agricultural College and there is nothing to suggest that this plant was not a cultivated ornamental.

FIGURE 1. Photograph of specimen of *Geranium pratense* [*G. W. Scotter 88105* Edmonton, Alta. (DAO)].

In the herbarium of the Biosystematics Research Centre (DAO) there is specimen of a white-flowered form of *G. pratense* grown by Dr. George Turner at Fort Saskatchewan, a few miles northeast of Edmonton. At the Edmonton site, about 120-150 plants of the typical mauve-flowered form of *G. pratense* were found. These plants may have escaped from a former garden since two other cultivated plants, *Saponaria officinalis* L., Soapwort or Bouncing Bet (*Scotter 88106*) and *Campanula rapunculoides* L., Garden Bluebell (*Scotter 88107*) are also present in the general area. If so, *G. pratense* has now spread into the grassed boulevard and along the edge of a parking lot. According to the Canadian National Railways Property Manager this area has been a parking lot since 1950 but there was a section house there in the 1930s and 1940s. This species may be readily distinguished from the rather similar *G. viscosissimum*, which occurs in Canada from southern British Columbia to southern Saskatchewan and southward into the United States, by having the undersurface of the leaves with pubescence along the nerves only, rather than being evenly pubescent over the whole undersurface. From *G. erianthum* DC. which occurs in Alberta only rarely in the extreme western part, but which it resembles superficially, *G. pratense* may be readily separated by the narrower and tapered towards the base divisions of the leaf, and the shorter rather than quite long glandular tipped hairs in the lobes of the calyx.

Anemone canadensis f. *dicksonii* was described by Bernard Boivin (1960) on the basis of a specimen collected by Rollo H. Dickson at Lacombe, Alberta in 1927. The flower differs from that of typical *A. canadensis* (Figure 2) in having the stamens completely petaloid (Figure 3). This is

FIGURE 2. Photograph of flower of *Anemone canadensis* [*Cody & Gutteridge 6813*, Lac la Biche, Alta. (DAO)].

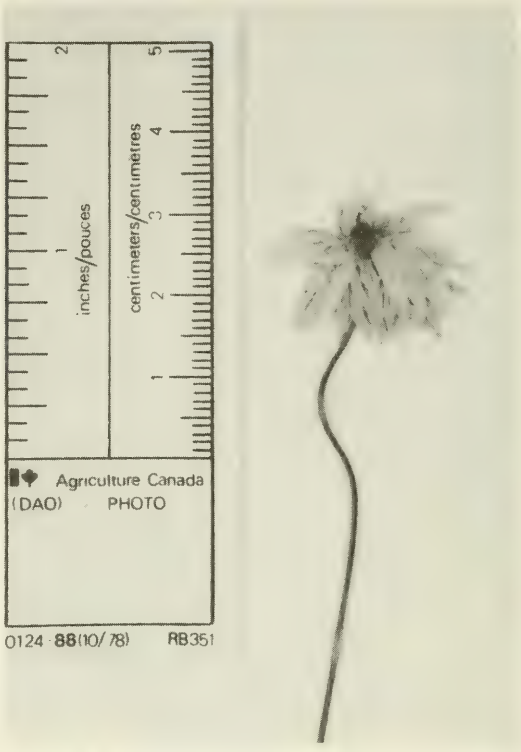

FIGURE 3. Photograph of flower of *Anemone canadensis* f. *dicksonii* [*Scotter 88102*, Lily Lake, Alta. (DAO)].

only the second published report of the occurrence of this interesting form of a species which occurs across Canada from Gaspé Peninsula, Quebec, and Nova Scotia, west to British Columbia, and as far south in the United States as West Virginia and New Mexico. Scotter has, however, seen f. *dicksonii* at a few other localities in the vicinity of Edmonton.

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White-footed Mouse, *Peromyscus leucopus*, Occupies Isolated Prairie Tract in Illinois

ROGER D. APPLEGATE

Division of Science and Mathematics, Parkland College, 2400 W. Bradley Avenue, Champaign, Illinois 61821
Present address: Department of Inland Fisheries and Wildlife, Wildlife Division, P.O. Box 1298, Bangor, Maine 04401.

Applegate, Roger D. 1990. White-footed Mouse, *Peromyscus leucopus*, occupies isolated prairie tract in Illinois. Canadian Field-Naturalist 104(4): 603–604.

Peromyscus leucopus was trapped in prairie grassland and prairie grassland/oldfield shrub habitats, 1.6 km W of Champaign, Illinois. These sites were 15 km from the nearest woodland/brushland and not contiguous with those areas.

Key Words: *Peromyscus leucopus*, White-footed Mouse, *P. maniculatus*, Deer Mouse, prairie, habitat selection, Illinois.

Peromyscus leucopus, the White-footed Mouse, is considered to be a woodland species over much of its range (Kaufman et al. 1983; Dueser and Shugart 1978; Van Deusen and Kaufman 1977), although Hoffmeister and Mohr (1957: 162) regard this species as a inhabitant of brushland and fingers of brushland extending into prairies. During the mammal-inventory stage of a remnant prairie restoration project near Champaign, Illinois, in April 1983, *P. leucopus* was trapped on an isolated prairie tract. The study area (40°06′51″N, 88°15′50″W) was a railroad right-of-way 1.6 km W from the city and approximately 15 km from the nearest woodland or brushlands. No areas of brushy or woody habitat connected the study site to adjacent brushland or woodland areas, but portions of the study site contained < 1 woody stem/m^2. The surrounding area was cultivated row crops or grazed pasture. Trapping in crop and pasture fields yielded no specimens of *Peromyscus* during this study.

Trapping was conducted with snap-traps on 4 transects, each 120 m long with 2 traps per station and 10 stations. Two transects consisted of prairie grasses (*Andropogon gerardii, A. scoparius*) and two transects were composed of grasses and *Prunus serotina* and *Rosa multiflora*. Trapping sessions lasted 10 consecutive days on each transect. I used Feldhamer et al. (1983) to separate *Peromyscus* spp. Specimens were deposited with the Museum of Natural History, University of Illinois, Champaign, Illinois.

P. leucopus constituted 49% (N = 41) of the total mammals trapped on the study area in 414 trapnights of effort. *P. maniculatus bairdii*, considered to be an inhabitant of grasslands, cultivated fields, and oldfields (Finck et al. 1986; Hoffmeister and Mohr 1957: 159), accounted for 34% (N = 14) of the catch. *P. leucopus* was trapped on all of the four transects; 35% (N = 7) of the captured *P. leucopus* were taken in the two grassland transects with the remaining animals (N = 13) being trapped on the two transects with mixed woody/grassy vegetation. Three of 7 *P. leuropus* trapped in grassland were adult males, 1 adult female, and 3 subadults (2♂, 1♀). In woody habitats, *P. leucopus* (N = 13) were: adult male (3), adult female (5), subadult male (4) and subadult female (1). All adult females were pregnant.

P. leucopus has been documented in grassland sites that were contiguous with woodlands, a factor that could allow dispersal of mice into grasslands from the adjoining woods (Snyder and Best 1988; Adler et al. 1984; Kaufman et al. 1983; Kaufman and Fleharty 1974; Geluso 1971). Clark et al. (1987) reported that *P. leucopus* foraged in prairie and lived in adjacent woodland ravines on their study area in Kansas. *P. leucopus* was absent from shrub sites with grassy understory (Van Deusen and Kaufman 1977); thus my observation of *P. leucopus* in grass dominated and shrub/grass habitats not contiguous with woodlands, is notable.

Acknowledgments

An earlier draft of the manuscript was reviewed by M. L. Hunter, Jr., and D. W. Kaufman and the final draft benefited from the suggestions of R. B. Allen and an anonymous referee. The prairie restoration efforts, for which this paper is a part, were supported by donations to the Grand Prairie Friends of Illinois and Educational Resources in Environmental Science, both of Champaign, Illinois.

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News and Comment

New Honorary Member and the 1989 Ottawa Field-Naturalists' Club Awards

As usual, OFNC awards for the past year were presented at the Soirée, held on 27 April 1990. One new Honorary Membership was assigned bringing our total of these to 25. During 1989 we lost long-time member Ibra L. Conners, who had joined the Club in 1933.

The Awards Committee did not consider that 1989 achievements justified giving either the Conservation Award or the Anne Hanes Natural History Award. Council accepted this position and strongly approved the Committee's nominations for the Service and Member of the Year Awards.

The citations for these honours were read at the Soirée, and certificates presented, by President Jeff Harrison. Citations are reprinted herewith. Unfortunately, Tony Erskine was unable to be present to receive his Honorary Membership in person.

Honorary Member: Dr. Anthony J. Erskine

To many contributors to *The Canadian Field-Naturalist*, Tony Erskine is known for his pivotal role since 1975 as Associate Editor for ornithology, a field that traditionally supplies a third of the journal's scientific content. Beginning in 1977, he was the editor for all bird papers, choosing reviewers and requesting and approving authors' revisions. Other obligations eventually obliged him to revert to a traditional role of an associate editor in the mid-1980s and provide only his own review, but he continued to advise in the choice of additional reviewers and to provide extensive supplementary comments for the editor's guidance. In the past two years, he has only had time to review selected papers. Tony has served with equal effectiveness under the editorships of both Lorraine Smith and Francis Cook and both have acknowledged his major contribution to the journal's direction, standards, and content.

To Ottawa members of the club, Tony is best-known as an active local member during his residence in Ottawa (1968-1977) and as a member of Council of The Ottawa Field-Naturalists' Club (1971-1977) on which he served as Recording Secretary for four years.

As an ornithologist, Tony has spent his professional career with the Canadian Wildlife Service which he joined in 1960. As a biologist, research scientist, and division chief, he has largely been concerned with measuring, monitoring, and managing migratory bird populations, specializing first in ducks and later in forest songbirds. He has authored or coauthored 202 papers, notes and book reviews in biology (and two in chemistry) in scientific and popular publications including *The Canadian Field-Naturalist* (16 papers and notes and 4 reviews), Canadian Wildlife Service publications, The Report of the British Columbia Provincial Museum, Syesis, Acta Ornithologica, The Auk, The Wilson Bulletin, Journal of Field Ornithology, Wildfowl, Nature Canada, The Ontario Field Biologist, The Blue Bill, The Blue Jay, *Trail & Landscape*, American Birds, Audobon Field Notes, Ontario Bird-banding, and The Nova Scotia Bird Society Newsletter. Tony has conducted field ornithology in British Columbia and other western provinces and states, Ontario, Quebec, and the Atlantic provinces. He has been based in Sackville, New Brunswick, since 1960 except for his decade in Ottawa.

Tony was born in England and came to Canada at age 5 in 1936. His parents, John and Rachel, settled in Wolfville, Nova Scotia, and contributed to the intense cultural commitment of that university town. John first farmed and later taught school, and was a remarkabely broad naturalist, long associated with the Nova Scotia Museum for which he conducted summer investigations first in botany and later in Micmac Indian pre-history. A brother, David, attained his M.Sc. in botany, did further postgraduate work in geography, and authored the definitive publication on the botany of Prince Edward Island. Tony went to Acadia, Queens, and the University of British Columbia, first taking degrees in chemistry, but his background triumphed and he finished in zoology and has ably carried on a family tradition of uncompromising scholarship and intensity in this field. He is currently involved in writing up the co-operative Breeding Bird Survey (Canada-wide) and the Maritime Breeding Bird Atlas.

Service Award: Joyce M. Reddoch

This award is to be presented to a member who has contributed significantly to the smooth running of the Club over several years.

These are the original words of the definition. The recipient is Joyce Reddoch, and at one it is seen that "significantly" can be read in the superlative, and that "several" here means a lot more than three or four. Joyce's contributions to our Club lie in a number of fields: involvement in

the production of *Trail & Landscape* from its inception, the last 10 years as its Editor; promoting the formation of the Conservation Committee and participating forcefully in its operations; leading Club outings; representing the Club in meetings with other organizations, including municipal and provincial government departments; serving as a Council member over 10 years in two separate periods; and writing numerous articles on a broad range of subjects of interest to our members — a total of more than 80 in *Trail & Landscape,* all but 10 of them being authored by her alone.

We look forward to seeing Joyce continue in Club activities. We are very pleased to present her with the 1989 OFNC Service Award Certificate.

Member of the Year Award: Deirdre Furlong

This is the only Club award that must be given annually. It is to go to the member judged to have contributed the most to the Club in the previous year. Making the choice in such a large Club, with so many active volunteers working in so many facets of Club interests, is obviously not always simple.

On this occasion we have all witnessed one of our Committees suddenly revivified and once again accomplishing its purposes. The Committee is Education and Publicity, and the person behind the surge in activity is Deirdre Furlong. She has led us back to a position where the Club exhibits were shown last year at eight events, and a number of requests for speakers and educational materials were successfully met. Our monthly meetings are again advertised in local media. Sales of Club items at monthly meetings and on other occasions such as the Ottawa Duck Club Art Show, have been greatly increased.

We have a renewed feeling of achievement, and the club is very pleased to recognize Deirdre's vigor in this important area with our 1989 Member of the Year Award Certificate.

BILL GUMMER
Chairman, Awards Committee

President's Prize, 1989: Michael Murphy

As a volunteer organization we are very dependent on individuals who contribute their time and efforts so that we can fulfill our objectives. It is, after all, the individual contribution that makes the OFNC what it is today. We honour those Club members who have been judged as excelling in their contribution during the past year. In point of fact, oftentimes the contributions made by our award winners involve longer term commitments. Now, more than ever, with increasing concern about the state of the environment, individual commitment is essential.

The President's Prize is given by the President to the Club member who, in the President's opinion, stands out for effort, accomplishment, or activity, not covered by the official awards of the club.

My choice for 1989 is Michael Murphy. Anyone who has had any involvement with the club in the last year has probably met Michael. He has served on the Conservation Committee, the Computer Management Committee, the Membership Committee and the Education and Publicity Committee. He is also the editor of the new "Greenline" insert in *Trail and Landscape* which is intended to inform membership about local conservation issues.

Michael has taken on the formidible task of representing the Club at City and Regional Council meetings and at local ratepayer association meetings. The list of issues that he has been involved with is impressive:

- Gatineau Park Management Plan
- Albion Road Wetland
- Clyde Avenue Woods
- City of Ottawa Environmental Management Plan
- Snow Dumps
- CMHC lands
- The Regional Waste Management Task Force

I've probably missed a few!

The point is that Michael has made a personal commitment to the local natural environment that is impressive. His efforts must come at some personal sacrifice of his free time. It is not just the amount of time that Michael has spent, it is my sense that his effectiveness has increased substantially as his knowledge of the issues broadened.

I feel that this commitment needs to be recognized and am pleased to present Michael with the 1989 President's Prize.

JEFF HARRISON
President, The Ottawa Field-Naturalists' Club

Changes in Membership Dues and Subscription Fees for The Ottawa Field–Naturalists' Club and *The Canadian Field–Naturalist*.

The Council of the Ottawa Field–Naturalists' club, at its meeting on 14 May 1990, approved the following amendments to By-Laws 4 and 5:

4. Membership Dues

The revised schedule of dues shall be as follows, commencing with the year 1991:

Individual	$23.00
Family	$25.00
Sustaining	$50.00

Life Membership shall be granted upon payment of a single sum of $500.00

5. Subscription Fees

The schedule of subscription fees shall be as follows: *The Canadian Field–Naturalist,* commencing with Volume 105,

Individual	$23.00
Libraries and institutions	$38.00

Trail & Landscape, commencing with Volume 24,

Libraries and institutions	$23.00

Additional postage on U.S. and other foreign subscriptions will be $4.00 Canadian.

The above dues and fees may be subject ot the General Sales Tax.

FRANK POPE
Chair, Finance Committee

Book Reviews

ZOOLOGY

Attracting Backyard Wildlife: A Guide for Nature-Lovers

By Bill Merilees. Whitecap Books, Vancouver/Toronto. 160 pp., illus. $12.95.

This is a splendid, uncomplicated book which delivers to the reader exactly what the title promises. Bill Merilees has always been a nature-lover, building bird houses and feeders with his father as a youngster and banding birds as a teenager. Now he is a professional biologist with a Master's degree in Outdoor Recreation and Education. Although Merilees lives in Nanaimo with a backyard full of local plants and animals, the information in this book is carefully tailored to conditions found across Canada; squirrel lovers in Toronto will find it as useful as apartment dwellers in Vancouver, who are told how to grow water lilies in a barrel or provide sweetened water for House Finches.

Merilees makes it clear that although a home owner may aspire to a variety of bird species — he himself had 12 different species visit his feeder one winter and he gives detailed instructions on how to attempt this for each season — there is joy also in attracting butterflies (with garden flowers) and bats (with bat houses) and toads (with toad lights). He even gives instructions on how to build nesting boxes for House Sparrows and Starlings for those inner city dwellers who are likely to have few other kinds of birds. Merilees is a practical person, however, and equally open to all creatures; he likes garter snakes because they eat slugs, and keeps Great Blue Herons near his house by stocking his fish pond with a supply of goldfish bought in the store. He observes that the white individuals are eaten first, then the orange, and finally the black ones in an interesting example of survival of the fittest.

Merilees comes out strongly against cats, which can quickly wipe out the wildlife one has set out to encourage. House cats are the primary killer of chickadees, and kill on average one small mammal or bird a month. Cats kill hundreds of millions of wild birds and mammals each year. He insists that cats be kept out of the backyard with cat-proof fences or by trapping.

The author also cautions against the use of insecticides for insects and herbicides for weeds. These poisons usually remain in the environment and build up in the food chain, sometimes weakening or even killing individual animals.

If there is a second edition of this useful book, I hope it will get rid of the few examples of sexist language such as backyard gardener . . . he, and butcher . . . he. We read that "Ever since the dawn of time man has feared creatures of the night. As ancient men huddled around their campfires, they heard strange squeaks, hoots, and howls." Were the women unafraid of these strange noises that they too did not seek the fire? We are left to wonder.

ANNE INNIS DAGG

Independent Studies, University of Waterloo, Waterloo Ontario N2L 3G1

Encyclopedia of the Animal World — Birds — The Waterbirds

By Robin Kerrod, Facts on File, New York. 96 pp., illus. U.S.$17.95; $21.95 in Canada.

This volume is one in a series of 12 that encompass the whole animal kingdom, but concentrate heavily on birds and mammals. It is most suitable for the older child. Arranged in systematic order, it devotes a few pages to each of the major bird families. The author describes the basic characteristics of family members such as their feeding, breeding, courtship behaviour, and so on. This is done in a language that is both readable and precise and that conveys the essential points in a clear, absorbable fashion.

The book is roughly 50% illustration and 50% text. The photographs used are excellent. Not only have they been chosen to illustrate the bird itself but also to highlight some important characteristic. Artwork is used to supplement the photos. This work, done by several artists, is also first class. Coloured illustrations again depict the individual species and black-and-white vignettes explain patterns of behaviour.

The author, even though he uses North American common names, is refreshingly non-partisan. Birds from all parts of the world are used

as representatives of their families and demonstrate those points which make it a member of that family. The author has also avoided the problem so often found in generalist books. That is, they tend to infer all birds mentioned live everywhere mentioned. The text is so well written that it is clear how each species' range is restricted.

Each bird family has a fact panel which shows, on a world map, the family distribution, and has codes for the fundamentals of diet, habitat, and breeding. The species (complete with scientific name) used as examples are also listed. The tiny map is often difficult to interpret and there are some weird anomolies (No shorebirds in Australia, no cormorants in Newfoundland, and an imaginative distribution of flamingoes in Europe, for example).

If you know any young budding naturalists this book would make an excellent gift. It would provide them with a broad perspective of the major bird groupings, their relationship to one another and some of the basics of avian biology. Beware, though, you may be asked to buy the other 11 volumes (which, if they are as good as this one would not be a bad idea)!

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

Birding in Atlantic Canada: Newfoundland

By Roger Burrows. 1989. Published by Jesperson Press Ltd., St. John's, Newfoundland. 175 pp., illus. $14.95.

I recently went birding in an area new to me. Much to my chagrin I could find little information on what birds to expect and the best places to go. I saw far fewer birds than I anticipated. I still do not know if this is normal for the area at this season; if I went to the wrong places or if the weather (it was raining hard all the time) were the major factors for this lack of success. What I really needed was a local guide book. Therefore I am always delighted when a new one is published. In this case I am even more appreciative as Newfoundland is a place I am fortunate enough to visit a couple of times a year.

In his five years in Newfoundland, Burrows must have explored all its little corners. And Newfoundland has a multitude of these quaint places; bays, harbours, villages, and capes. The author starts at the Sydney, Nova Scotia, to Port aux Basques ferry and works his way up the northern peninsula, down through St. John's to Argentia to end at Cape St. Mary's. He thus divides Newfoundland into 22 segments.

Each chapter is devoted to one of these segments. The author starts with a map which shows the roads mentioned and the major geographical features. Then follows a narrative which guides the reader along these roads, indicating the best places to stop and what birds might be expected there. Burrows explains the seasonal changes to be expected and the location and conditions under which rarities turn up. This is important as Newfoundland gets a large number of vagrants, particularly from Europe. Anyone, visitors included, could be lucky enough to spot an exciting bird and being aware of the possibilities is an asset.

Many of Newfoundland's "common" birds are novel for central Canadians and Burrows does an excellent job on these. If you want to see Puffins, Black-headed Gulls, Dovekie, Gannets, or shearwaters, to name a few, then this book will lead you to the right place at the right time. I only have two complaints with the book. Burrows could have provided some information on boat hire. A simple list at the back of the book with names, addresses, telephone numbers, and current prices would have been helpful to a visitor. Also I found the index a little spartan. Someone with less knowledge than I have of Newfoundland would have some trouble in finding specific locations.

Overall it is a fine little book and will be very useful to visiting birders. In fact reading it will whet your appetite and make you want to visit! Burrows does not transmit some of the magic that is Newfoundland: that was not his purpose. You will have sit in one of those bays, as the sun sets, and watch Humpbacks playing with their calves as Kittiwakes swirl overhead, to do that. But this book will help you get there.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

A Bibliography of British Columbia Ornithology, Volume 2

By R. Wayne Campbell, Tracey D. Hooper, and Neil K. Dawe. 1988. Heritage Record No. 19, Royal British Columbia Museum, Victoria. 591 pp. $30.

This volume is the third of four bibliographies of British Columbia vertebrate fauna and complete the compilation of bird literature for the province to about 1983. The book consists of a brief introduction and explanation of its organization, a list of sources, a list of citations (numbers 2101 through 4635), two indices, and a list of the authors' addresses.

The list of bibliographic sources is lengthy and reveals a comprehensive search. Readers without Volume I may not realize the full extent of this search. The sources listed in Volume 2 are for citations in that volume only. Both volumes are required for a full list of sources searched. The authors state that the "The" has been dropped from journal titles that start with *The* (e.g. *The Auk* is listed under A, not T), but their example of *The Ring* is, in fact, listed with three others under "The" instead of under "R". Apart from some specialty journals like *Wader Study Group Bulletin*, most journals that might contain British Columbia bird information appear to have been searched. A notable omission is *Birdfinding in Canada*. Most of the journals appear to be listed correctly, but *Colonial Waterbirds* started under that title at Volume 4 (1981), not Volume 1. The bibliography lists both this journal and the *Newsletter of the Colonial Waterbird Society* as continuing from the society's annual proceedings. It was the journal that did so.

An improvement in Volume 2 over Volume 1 is the listing of citations alphabetically by senior author rather than merely in the order acquired, although a few are slightly out of order. The oldest reference included is from 1866, and the newest from 1987. As a bibliographer of Alberta and Manitoba ornithology, I am very aware of how easily items can be missed. I tested the authors' comprehensiveness by seeing how many 1983 or earlier references by authors whose names start with A through C in my own British Columbia bird files were listed in neither of these two volumes. After eliminating all Anonymous reports, items from local newsletters, and articles from *Birdfinding in Canada*, I found that 47 references in my files were not listed. Most contain only brief notes on British Columbia birds or are in obscure sources (e.g. a fossil bird reported by Cope in the *Journal of the Academy of Natural Sciences* in 1894). A few were in journals covered by the authors, including three by Campbell himself. These omissions do not detract from the overall usefulness of the bibliographies and can be added in future bibliographies covering subsequent years. A number of bibliographies to surrounding areas and to species groups are included. These might better have been listed in an appendix.

One of the best features of Volume 1 was the inclusion of indices to authors, species, and geographic areas of the province. Listing of citations alphabetically in Volume 2 makes an author index unnecessary and it has been eliminated, although an index to junior authors would have been desirable. The geographic index in both volumes is keyed to map numbers, as shown on an accompanying map. The species index in Volume 1 was the most comprehensive of any province to date, listing all references to a species, not just those in which the name of the species appears in the title. Volume 2 goes further, indexing each species to up to 75 subject categories and 12 subcategories. Species are indexed by current name except that Pacific Loon is listed as Arctic Loon and citations to Upland Sandpiper are divided between this current name and Upland Plover.

This very useful compilation is enhanced by black-and-white sketches of birds on each page of citations, by its layout, and by a minimum of typographical errors (I noted only seven).

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M 1X4

A Field Guide to the Birds of the USSR

By V. E. Flint, R. L. Boehme, Y. V. Kostin, and A. A. Kuznetsov. (Translation by Natalia Bourso-Leland), 1989. Princetown University Press, Princetown, New Jersey. 353 pp., illus. U.S.$27.50.

This book is a paperback version of a 1981 translation of a book originally written in Russian and published in 1968. The 1981 hardcover version was a major contribution to birding. It filled an enormous gap in field guide literature. But it was outrageously expensive (three to four times the price of an equivalent North American guide). This latest paperback version is much more reasonably priced, and it is now an affordable gift.

The 1981 translation included updated information and revisions by V. E. Flint. The paperback version is only a reprint of the 1981 edition. This is

unfortunate as there are a number of places that could do with improvement. Take, for example, the English names; in most cases the accepted North American name is used (Common Loon instead of Great Northern Diver) but sometimes it is the British name (Sand Martin for Bank Swallow). Some names I have not heard before (Tufted Pochard for Tufted Duck). I cannot see the logic used to separate "Eurasian" from "European". The European Nightjar has a more Asian range than the Eurasian Roller, for example. It would be a simple task to standardise on one set of names (the North American) and add the other in parentheses.

The name confusion is only a minor inconvenience. A more serious problem is the lack of usable information on the separation of difficult species. I do not believe anyone could use this book to separate such species as the kites, harriers, shorebirds, or nightjars. The plates are fairly well done but lack the precision necessary to be fully useful. The text generally reinforces what can be seen in the plate and adds little supplementary information. It contains too many statements like ". . . similar to . . . and difficult to distinguish from . . .", without attmepting to use many of the subtle field marks discovered by the Europeans in the last few years. The traveller would still be wise to carry one of the excellent European guides, and, if going eastward, an Asian guide too.

Each species has a range map. These depict the entire USSR and are about 3″ × 1.5″. This is satisfactory for widespread birds but is poor for those with restricted distributions. For some of the latter it is almost impossible to use the map given effectively. A larger scale map is the obvious answer in these cases.

Some information is given about travel restrictions and how they affect birdwatching. It might be asking too much but an update, particularly as it relates to the new policies for freer movement, as instituted by Mr. Gorbachev, would have been most useful.

Despite these problems this is a most valuable book. It is the only, readily-available, source of information on one of the largest regions of the world. It is produced in the easy-to-use format of a western field guide, with respectable colour plates and well-written text. An essential purchase for any traveller to the USSR, and an interesting purchase for the avid birder.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

A Field Guide to the Birds of Mexico

By Ernest P. Edwards. 1989. Published by E. P. Edwards, Sweet Briar, Virginia. 118 pp., illus. Cloth U.S.$23.50; paper U.S.$19.50.

Ernest Edwards has re-issued his field guide with an additional 26 plates, to bring the total number of illustrated birds to 870. This, the author rightly claims, is many more than is illustrated in any other Mexican field guide. However the difference between this book and, say, Peterson's *Field Guide to the Mexican Birds* lays in plates of common North American species. Edwards has added plates of the common warblers, finches, shorebirds, and so on; birds familiar to the North American birder. Peterson concentrates on the Mexican specialities only (and gives reference to his other guides for the commoner birds.) Also, Edwards crams 25 to 35 species per plate in comparison to Peterson's 8 to 18. This means many species are represented by a 1″ drawing. Peterson's illustrations are about twice the size or better.

The quality of the illustrations is very good, far better than in Irby Davis's *Field Guide to the Birds of Mexico and Central America*. Their style is similar to, but not quite as precise as in Peterson. I can find the usual details that are not quite right (the overly-domed head of the Grasshopper Sparrow, the slightly-large Hermit Thrush, the anaemic Violet-crowned Hummingbird, and the over-bright bill on the Grey-necked Rail, for example). When the author added in new plates he did not reorder the sequence of species. So Chachalacas appear 40 plates apart. Similarly ducks, hummingbirds, trogons, and hawks all occur on different plates. One plate the author should have added is "hawks overhead", a position in which we often see them. Something has gone strangely wrong with the Golden-fronted Woodpecker title on Plate 23.

The text is very sparse. Generally each species is given only 4 to 8 lines. This allows for a distribution code, one or two lines on behaviour and voice, followed by a two or three line description that reinforces the plates. For example, could you identify a 9-inch shorebird from "Mottled grayish-brown above; belly and untacs (a new word by the author to denote undertail coverts) white; breast appears dark and contrasty, with narrow black on pale brown; legs dull greenish". The descriptions do not provide much additional detail over the plates.

The nomenclature used by the author comes from his own *Coded Workbook of Birds of the World* and does not always match the accepted AOU version. He lists an abbreviated version of the AOU name in parentheses in the text (as an alternative not an alternate name please Mr. Edwards) so you can cross reference if needed.

So what are the reasons for buying this book? It does have a more complete set of illustrations than any other guide for Mexico, and thus it is easier to carry than two or three Petersons. It lists the common Spanish as well as English names. The plates show the entire bird in all cases, not just the head (as Peterson sometimes does). Why not buy one for your partner to carry. It is useful, up-to-date, and lightweight. I will still carry my old, but trusty, Peterson.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

Whales of the World

By Nigel Bonner. 1989. Facts on File, New York. 191 pp., illus. U.S.$22.95; $30.95 in Canada.

This book could be categorised as an introduction to whales, and it is designed to be read through, rather than sampled; it is certainly not a book of reference. In this it differs markedly from one of the last of such general works: *The Natural History of Whales and Dolphins* by Peter G. H. Evans (Christopher Helm, London, 1987) which was a compendium, with great detail. I would therefore rate Bonner's book as valuable for general readers, since it is well balanced and readable, but of less value to experienced naturalists, since there are no detailed references, so that statements of fact cannot be verified or followed up. The book deals well with the diversity of modern baleen and toothed whales, their ecology and behaviour, and their past and present relation with people.

There is a risk in dealing on a world scale with a group of animals (even with such a limited number of species — about a hundred), and that is the improbability of being knowledgeable about all species and their geography. On biology, I can only fault Bonner on one major count — the Sperm Whale (pages 84-85) does not seem to have a harem structure in the reproductive schools. Rather, according to Hal Whitehead and Tom Arnbom (*Canadian Journal of Zoology* 65: 913-919, 1987), from their studies around Galapagos, several large males can occur together in each group of females and immatures. Individual males move between groups quite rapidly, presumably mating with different oestrous females.

I have also some geographical quibbles, mostly with Bonner's treatment of the Canadian scene. On page 56, there is a puzzle with the English merchant who found 20-30 Basque whaling ships on the Grand Banks in 1578. Even in modern times, the Grand Bank of Newfoundland was out of range of whaling from shore stations because of the length of towing. I find on reading J. Travis Jenkins [(1921) 1971: *A history of the whale fisheries*, Kennikat Press, Port Washington, New York], ambiguities over whether or not the Basques flensed whales at sea. There is no evidence of it, and we now know that they used fry-works ashore at Red Bay, Labrador, in the late sixteenth century. Therefore, I think it likely that the spread of Basque fishing and whaling westward from Iceland to Newfoundland was brought about by fishing at sea (and coastally) and whaling close to land. On page 132, the well-known "resident coastal population of about 210 Killer Whales in some 20 pods" of the northwest North American coast does not live only in Puget Sound but also in the wider straits of Georgia and of Juan de Fuca. I have some difficulties also with numbers. The eastern North Pacific Grey Whales at present number some 15 000 and sustain a Soviet catch, taken by catcher vessel for the benefit of the Chukchi people of northeastern Siberia, of 150-200, or about 1% of the population, per annum, without any decrease (R. R. Reeves and E. Mitchell, *Canadian Field-Naturalist* 102: 369-390, 1988). Bonner (page 60) states that American whalers in the Bering, Chukchi, and Beaufort seas killed some 18 650 Bowhead Whales (including lost whales) over 68 years, or a mean of 274 a year, and depleted them. Yet he estimates the original stock of bowheads there as 60 000 (page 55) or, by logical implication (page 65) as 30 000. Unless the Bowhead Whale has a much lower reproductive rate or higher natural mortality rate, or both, than the Grey Whale, even the latter figure for population must be too high.

I remain unhappy with other statements that tend to play down the present status of some species as against their primeval one; e.g., that of the aggregated Humpback Whale stocks, stated on page 90 to be "of the order of 10 000, perhaps only 9 percent of the pre-exploitation stock". This may be true, because of the paramount importance of the highly depleted, originally very numerous, Antarctic stocks. But we have one stock of

humpbacks, in the northwest Atlantic, which with protection since 1951 (i.e., 40 yrs) has increased from low numbers to some 4000 animals (Hal Whitehead in *Canadian Field-Naturalist* 101: 284-294, 1987), and even some of the stocks migrating to the Antarctic, such as that on the east coast of Australia, are recovering well. (R. Paterson and P. Paterson *Biological Conservation* 47: 33-48, 1989). It seems to me that we are still fighting the old whaling battle, talking about numbers. So long as the status of the species is secure, why worry about numbers if we don't exploit them? What we should be interested in is their accessibility to people. The Blue Whale is now highly accessible to whale-watching in such places as the Gulf of St. Lawrence, along the Californian coast and in the Sea of Cortez, at Sri Lanka (when political stability returns), and off some Indonesian islands. But I agree that the very low numbers of the Antarctic Blue Whales mean that the Antarctic ecosystem is vastly changed from what it was before whaling began there. I agree with the author that the large, pelagic whales in the post-whaling era are probably the least at risk among Cetacea; that drift-netting is probably the major risk to many smaller, pelagic species and those living inshore; and that some of the river dolphins are the most threatened of Cetacea.

The illustrations to this book are well-chosen and drawn or reproduced, the text free of major errors.

D. E. SERGEANT

325 Main Road, Hudson, Quebec J0P 1H0

Review of Methods of Evaluating the Physical Condition of Wild Ungulates in Northern Environments/Evaluation de la condition physique des ongules sauvage dans les regions nordiques

By/Par Jean Huot. 1988. Centre d'études nordiques, Université Laval, Québec. 30 pp. English; 32 pp. Français. $12.

Huot notes that, for ungulates and especially Caribou, habitat evaluation requires rigorous field study over large areas and several seasons. This makes it an expensive and time-consuming research with often questionable results. Uncertainty can lead to misinterpretations which result in disastrous management decisions with results such as overexploitation. Population surveys, even in the barren lands where herding behaviour and the lack of trees make them relatively easy, are also expensive and often result in broad estimate with 100% or greater error factors. Even in the early days of game management, Leopold complained about the over-reliance on population estimates which are only evaluations of a single place and point in time. A large population density can mean either a healthy herd or a pending population crash.

For these reasons, Huot is evaluating other methods to determine the physical condition and nutritional status of large ungulate populations. His criteria are that these methods should be relatively inexpensive, effective, easily replicated, scientifically valid, require limited training, and provide data for management decision making. This short publication provides a review and comparative critique of methods used to evaluate the physical condition and diet quality of ungulates, especially relevant to Caribou.

A variety of methods are discussed and compared in a concise but authoritative manner. These include measurements of body weight, morphometric data, glands and organs, fat reserves, blood chemistry, hair, rumen, fecal matter, parasites, behaviour and demographic vigour. Huot's conclusions are that none of these methods are clearly the best, some being more appropriate or feasible under different circumstances. None are reliable as a sole parameter on which to base conclusions or management decisions. The major problem is that many of these approaches lack a good baseline database for comparative purposes. He concludes that there are two critical seasons for measurements: spring, when animals are in generally poor condition, and fall, when they are generally in their prime. Single season studies are questionable. In chemical and some other types of analyses he recommends a minimum of 50 samples within the same region and a maximal 15-day period. This can restrict the research potential, especially if one does not wish to damage the herd by sacrificing large numbers of animals. In any case, Huot emphasizes the need to correlate the physical measurements with a good understanding of the animal and habitat ecology as well as any abnormal disturbances which might have occurred in the area.

A table at the end, comparing the advantages and disadvantages of the various methods reviewed provides a good overview of the conclusions. A comprehensive listing of

references is provided for further reading for those who are interested in any particular approach. This is certainly recommended as an initial source for anyone contemplating research on northern ungulates. It provides a concise but valuable summary of methodology, utility, and shortcomings.

WILSON EEDY

R.R. 1, Moffat, Ontario L0P 1J0

Swallows and Martins: An Identification Guide and Handbook

By Angela Turner and Chris Rose. 1989. Thomas Allen & Son, Markham, Ontario. viii + 258 pp., illus. $51.95.

This identification guide and handbook starts with a 32-page general introductory section which covers the morphology, plumage, classification, distribution, migration, feeding, foraging, competition, behaviour, breeding biology, population sizes, and conservation of the family Hirundinidae as a whole. Most of these topics are further broken down into subtopics.

Next is a section made up of 24 colour plates illustrating almost all the swallow and martin species covered in the book. Fieldmark descriptions and three-colour range maps are on the facing pages. The third section is systematic and its 149 pages describe the field characters, habitat, distribution, population, migration, food, social organization, sociosexual behaviour, breeding, voice, appearance (including measurements), and races for each species. The book concludes with a 21-page bibliography and a four-page index of English and scientific names.

The book's range of swallow and martin species is on the conservative side. Turner recognizes 74 species; Howard and Moore (1980) recognized 77 species and Clements (1977) 81 species. Differences are due mainly to the splitting of Northern and Southern Rough-winged Swallows (1983), the discovery of the Red Sea Swallow (1984), and differing opinions on how to treat the African Rough-winged Swallows (also known as Sawwings).

This book contains a wealth of information in a style that is both easy to read and easy to understand. An abundance of facts is presented, but not in such a way that the reader feels overwhelmed or intimidated. The author's language and style make for pleasant reading by any armchair naturalist and the level of detail will appeal to any layperson, naturalist, or scientist interested in swallows and martins. The only information that might be lost to the layperson occurs those times when the author uses scientific names to describe prey species.

The colour plates are good, with species being illustrated both perched and on the wing. The range maps are generally clear; although there are some cases where a better scale could have improved the map's usefulness. Although the range maps start on page 34, the key to the maps is on page viii.

There is very little to criticize in this book. Readers who want to check up on references may have a hard time finding the source as the state/province/country of less well-known publication locations is not given and no page numbers are provided. Factual errors and writing errors are virtually absent.

Although this book bills itself as an identification guide, North American birders will not need to use it for identifying local swallows and martins as the current field guides do an admirable job in this respect. However, for North Americans who wish to learn more about local swallows and martins, or learn about swallows and martins overseas, this is an ideal source of information.

All in all, this is an excellent book and it is heartily recommended for anyone who wishes to become better educated about swallows and martins.

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Howard, R., and **A. Moore.** 1981. A Complete Checklist of the Birds of the World. Oxford University Press, Oxford. [Pages 349–354]

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STEPHEN GAWN

67-D Bowhill Avenue, Nepean, Ontario K2E 6S8

Fishes of the Thunder Bay Area of Ontario: A Guide for Identifying and Locating the Local Fish Fauna

By Connie Hartviksen and Walter Momot. 1989. Wildwood Publications, Thunder Bay, Ontario. 282 pages, illus. $24.95.

This is a handy guide to the fishes of the Thunder Bay region of Ontario which includes the area from the north shore of Lake Superior to 52° N, over 600 km northwards. Eighty-two (according to text) native and introduced species (some now extirpated) over 40% of Canada's freshwater fish fauna, have been recorded from the region.

The 23-page introductory portion of the book includes the following sections: Preface, Acknowledgments, Notes to the Reader, About the Authors/Illustrators, Some Important Publications about the Canadian Fish Fauna, A Summary of North Ontario Fishing, Map of the Region, Description of the Study Area, Glaciation, Hydrology and Fish Distribution, External and Internal Anatomy of Fishes, Checklist of Species found in the Thunder Bay area, and Key to Fish Families. Most of these sections provide pertinent information, but the list of important Canadian fish publications seems out of place. The significance of angling to the region is revealed by the presence in 1980 of 44 600 resident and 24 300 non-resident anglers. The description of the river basins will assist anglers in choosing a vacation spot. The accounts of deglaciation and postglacial movement of the fishes provide interesting reading. I did not find any discussion of environmental issues.

Species accounts occupy 210 pages of the book. For each species the reader is given the common and scientific names, an illustration, description of the fish, its relationship to man, the first record for the area and its location, and other common names. Under description, biological as well as descriptive information is given. The pen-and-ink drawings provide a good impression of the fish and enough detail to assist in identification. Identification is further assisted by a pictorial key with a list of diagnostic characters at the beginning of each family. Much new information on fish distribution is provided. The scientific name for the Deepwater Sculpin, however, is now generally accepted as *Myoxocephalus thompsoni*, not, as in the text, *Myoxocephalus quadricornis*.

A lake inventory, glossary, supplemental reading list, and index complete the book. The lake inventory gives the latitude and longitude of the lake, a geographic (?) code, and a list of the known fish species. A colored map with fine details of rivers, lakes, and road is provided in a pocket on the back cover. The scale is 1: 600 000.

This is an excellent guide for the angler in northern Ontario. It also provides information useful to the ichthyologist and naturalist. I highly recommend it.

DON E. MCALLISTER

Ichthyology Section, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Predators and Predation: The Struggle for Life in the Animal World

Edited by Pierre Pfeffer. 1989. English translation by Mark Howson. Facts on File, New York. (Originally published in 1985 by Editions Balland as *Qui mange Qui*). ix + 419 pp. U.S.$50.

Had this encyclopedic reference work been around in the middle of the last century, Tennyson's celebrated poetic description of "nature red in tooth and claw" might never have been written. In scores of examples, the 70 contributors to the volume do their best to dispel the antiquated (but still pervasive) notion of "hostile, immoral, and wilfully cruel" animal predators, equipped with an arsenal of fangs, claws, pincers and tentacles straight out of a grisly late-night horror film. Instead, the book attempts to present a more balanced overview of the role of predators in natural systems, devoting as much space to such unlikely predators as the European Dormouse and Scarlet-Chested Sunbird as it does to their more spectacularly-armed predatory colleagues.

As a guide to the gastronomic habits of over 500 vertebrate and invertebrate species, *Predators and Predation* is one of the most ambitious, if misguided, reference volumes on this topic I have seen to date. A typical 500-word entry contains a physical description of the predator, its geographical range, and highlights of its natural history, as well as a description of how it hunts and captures its prey. For quick reference, black triangular symbols are embedded in the text to highlight both the common prey species and the predators of the animal in question. But it demands a great deal of patient browsing to appreciate the broader intent of the authors.

Despite the ambitious scope and scale of the book, it's difficult to determine what audience the editor had in mind. Outwardly, it has the dimensions and appearance of a coffee-table tome, with an eye-catching glossy dust cover featuring a color photograph of a Grizzly Bear making a meal of an impressive salmon. Yet inside, the volume is completely, disappointingly unillustrated; not a single plate or line drawing is provided to enlighten the reader as to the appearance of any of the myriad creatures described in the entries. The prose style, though generally quite lively and readable, is somewhat uneven, in spite of the homogenization of the contributions of 70 authors by a single translator. Although the book is billed as being "accessible to both amateur and professional naturalists and ecologists", full comprehension demands a relatively sophisticated biological vocabulary ("*. . . In virtually all alcyonarian species, nutrition is provided by minute planktonic organisms that are ingested through the buccal orfices of the autozooids . . .*").

It doesn't quite make it as a reference book, either. Margin notes provide taxonomic classification up to family level, and scientific names are included alongside the common names at the beginning of each entry. Perplexingly, though, the editors chose to arrange the entries alphabetically by the common name of the predator (adjectives included), rather than by scientific name within a consistent taxonomic framework. The result is an illogical hodgepodge of hard-to-locate entries, with no provision of scientific or alternative common names in the index (e.g. one would have to know in advance that the Cougar or Mountain Lions, *Felis concolor*, is also called the Puma in order to find it at all. And who's likely to look for the Spiny Anteater, *Tachyglossus aculeatus*, under "S" . . . for Short-Nosed Echidna?).

Though we're reassured in the Acknowledgements of the sterling scientific pedigrees of the contributors, they are identified only by a set of cryptic initials after each text entry. Nowhere in the book is there a reference to any original literature. It's a pity, really; there's a wealth of interesting information to be found between these covers. With a bit more attention to organization, indexing and literature citation, this could have been a useful reference volume, instead of a voluminous, loosely organized, interesting but ultimately eccentric collection of animal trivia.

DAVID T. BROWN

Institute of Urban and Environmental Studies, Brock University, St. Catharines, Ontario L2S 3A1
Present address: Department of Renewable Resources, MacDonald College of McGill University, 21 111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0

Flight Strategies of Migrating Hawks

By Paul Kerlinger. 1989. University of Chicago Press, Chicago. xv + 375 pp., illus U.S.$19.95.

This book is concerned with basic quantitative research into the natural history of raptor migration. By studying the morphological, physiological, and behavioral adaptations for migration in each raptor species, Kerlinger aimed to determine how natural selection has shaped flight strategies.

An individual bird that travels less than 300 km one way is considerd to have a short migration, while over 1500 km is a long migration. Most birds have a north-south or latitudinal migration but Kerlinger points out that the Prairie Falcon and, to a lesser extent, the Northern Harrier, Red-tailed Hawk, Bald Eagle, and Great Horned Owl have a longitudinal component of eastward movement. The most northerly *tundrius* Peregrine Falcons migrate farther south, leap-frogging over the less migratory *anatum* and more sedentary *pealei* subspecies. Adults often precede immatures in their migration, in both directions.

Kerlinger discusses seven hypotheses as to why males and females or adults and immatures may migrate at different times and to different places: the social dominance, body size, arrival time, character divergence, feeding efficiency, molt, and migration threshold hypotheses.

Methods of studying migration, structure of the atmosphere, the role of wind, topography and geography, water crossing, altitude of migration, flocking behavior, flight speed, flight strategies, and the theories of flight mechanics, all receive appropriate attention. Kerlinger has studied meteorology and the physical principles of aerodynamics, and has consulted the relevant Canadian and European literature. No other book deals adequately with all these subjects. He writes in an interesting and informative manner.

My only complaints are that flight speeds are given in meters per second, nowhere converted to miles per hour for the benefit of oldtimers, and that the 10 000 km one-way flights of some Swainson's Hawks from Saskatchewan, and the even longer flights of Peregrine Falcons from the Arctic shores to Patagonia, are given insufficient emphasis. This book is a must for all raptor enthusiasts.

C. STUART HOUSTON

863 University Drive, Saskatoon, Saskatchewan S7N 0J8

Birding, Jasper National Park

By Kevin Van Tighem. 1988. Parks and People, Jasper, Alberta. 73 pp., illus. $5.99.

This well-designed booklet can serve as a model for bird-finding guides to a local region, in this case one of Canada's most popular National Parks. Its strengths are the succinct seasonal charts to show the expected times that 254 species are present, essays on the 14 (of 17) main habitat groups, with overly diagrammatic, unscaled, but easy-to-follow maps of 13 proposed birding routes within Jasper National Park. Nineteen sketches by Andrew A. LeMessurier add to its attractiveness. The unusually detailed, 9-page index surprisingly fails to give page numbers for the species in the seasonal charts. Species names are given correctly in the seasonal chart, but two are given incorrectly in the text. Beginners and expert birders alike will find this booklet a necessity on their next visit to Jasper.

C. STUART HOUSTON

863 University Drive, Saskatoon, Saskatchewan S7N 0J8

Ospreys: A Natural and Unnatural History

By Alan F. Poole. 1989. Manomet Bird Observatory (distributed by Cambridge University Press, New York). 246 pp., illus. U.S.$30.00.

Alan Poole has drawn on ten years of his own field studies in New England and a thorough review of the world literature to produce this well-written, attractively illustrated, non-technical account of one of our most appealing birds. His topics include taxonomy, distribution, migration, diet, breeding, and population regulation. Among other threads is an upbeat conservation success story.

Once North Americans comprehended that the Osprey, at the top of the food chain, is one of our most sensitive environmental indicators, a revolutionary new human approach to environmental protection resulted. Poole documents clearly the drastic, dose-related decline in Osprey reproduction, mediated in part by egg-shell thinning, when DDT was sprayed over coastal marshes in the early 1960s. Osprey breeding success plummetted and the coastal Ospreys seemed doomed to extirpation. A group of lawyers brought suit against the Long Island Mosquito Control Commission, establishing the precedent for what we now call environmental law. The Connecticut and Long Island populations recovered quickly once local use of DDT was banned. Surprisingly few Osprey populations elsewhere suffered ill effects from DDT, dieldrin or mercury, and Ospreys are remarkably tolerant to PCBs and, as yet, acid rain.

Osprey populations are frequently limited by a lack of suitable nest sites, but this deficiency is easily corrected. Now 70% of coastal pairs between Boston and New York City are using man-made platforms, which offer higher reproductive success than former nests in trees. Ospreys have adapted to high human densities nearby. In other states, such as Pennsylvania, Ospreys have been reintroduced successfully by "hacking out" young in suitable localities. Under the protection of the Royal Society for the Protection of Birds, almost a century after persecution destroyed the last breeding birds, Ospreys have recolonized Scotland and their population, like that in New England, is doubling every five to seven years.

Everyone interested in raptors, pesticides, and environmental conservation will enjoy reading this excellent book.

C. STUART HOUSTON

863 University Drive, Saskatoon, Saskatchewan S7N 0J8

Lizards of the World

By Chris Mattison. 1989. Facts on File, New York. 192 pp., illus. U.S.$23.95; $30.95 in Canada.

The major fault that is to be found with this book is with the first sentence: "There are very few parts of the world where lizards are not the most conspicuous elements of the reptile fauna". It would not seem that Canada and the adjacent USA comprise "few" places, but 20 years of field herpetology have left me able to count the places I have seen lizards on the fingers of one hand. This perhaps makes my failure to find any errors of fact in the remainder of the book less interesting than it would be were I a pet-keeper or an Australian. Evolutionary theory, on the other hand, is the acid

test by which the writers of popular books usually fail, but there are only two insignificant lapses here: amniotes are called "the upper branches of the evolutionary tree" (page 86), and licking the eyeball (a derived character of gekkos), is said to be "retained" (page 108) in those gekkos with functional eyelids, whereas it is likely a preadaptation which made the fused transparent eyelids of other gekkos possible.

A few slightly crude pen drawings appear among a marvellous profusion of stunning, well-reproduced, colour and black-and-white photographs, almost all by the author. There are no posed-dead specimens or half-starved captives here: these beasts are prepared to spring, crawl, or amble off the page, caught in dynamic poses reminiscent of the best of Audubon's birds. A *Physignathus* (page 135) could be the basis of all Chinese dragon lore, a *Eumeces laticeps* (page 159) could be the work of a Scythian goldsmith, and the tongue-and-eye spread (pages 42-43) is as succulent as a meal of oysters.

The text is written as anecdote, well informed by the results of recent research. Chapters briefly treat the origin, anatomy, ecology, feeding, defence, reproduction, distribution, and captive care of lizards, followed by a systematic account, by families, and an account of amphisbaenians, which are included because they "would otherwise slip through the net of this series". There are few infelicities: the Komodo Monitor is said to be allopatric from "other large carnivorous mammals", the green blood of *Prasinohaema* skinks is passed over rather too casually, and the index contains only the names of taxa, though many examples in the functional chapters are cross-referenced in the systematic chapters. Acid-free paper, strong binding, handsome layout: this book is a credit to the author and the publisher.

FREDERICK W. SCHUELER

Research Associate, Herpetology Section, Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

Introducing Birds to Young Naturalists

By Ilo Hiller. 1989. Texas A&M University Press, College Station. 69 pp., illus. Cloth U.S.$21.50; paper U.S.$12.95.

Introducing Birds to Young Naturalists is appropriate for children aged 14 to 16 provided those children already possess a sincere interest in natural history. Unfortunately, unlike some other natural history publications designed for children, this book contains not enough material organized in a fashion that could be easily adapted by a "teacher" working with youngsters. The chapters on nest boxes and feeders do provide a little of this hands-on direction but better treatments are available in numerous other publications. Three chapters, Eggs, Feathers, and Bird Songs, are good introductions to unique birds features.

The book is a general interest publication on birds and to its credit does not get "lost" in species detail. It makes no attempt at teaching how to identify, but rather, presents information on the generalities of birds. Its approach is to discuss birds in groups, for example, sample chapters review woodpeckers, jays, bluebirds, hummingbirds, and pigeons and doves. Within these chapters, reference is made to some species differences but the dominant content is aimed at telling of how this group "performs". A strong case can be made that not all groups are represented as waterfowl, raptors (except owls), and grouse are not treated.

As a Canadian reading this book, an obvious weakness is its lack of treatment of birds in winter. Although a chapter dealing with feeders is included, its reference to the need for water at a feeder site is not consistent with most Canadian winters when feeder use is most important. Furthermore, the chapters on bird "groups" don't consider birds that overwinter or the biology of overwintering birds, something I feel is important for young naturalists to understand and appreciate. For many Canadian children, their first, and perhaps main exposure to birds, results from observations at a winter feeder. In fairness to the author it should be pointed out that it was his intention to provide a review of the bird fauna and biology of Texas where winter severity is less a factor.

A nice feature of this book, unlike many other general interest bird books, is that the text generated the photos and not the reverse. The photos are excellent, but it is very obvious from the book's format that it was the written word that was the basis for photo selection. The photos do complement the written text.

The book is well written, the layout good and the production quality excellent. A "Glossary" of terms would have been a valuable addition to the book and considering the intended audience, it is surprising one is not included. Because of its content, *Introducing Birds to Young Naturalists* will appeal to persons living in the southern United States. Unfortuantely, the book is not appropriate to the Canadian children's marketplace.

PETER CROSKERY

RR 1, 50 Ridge Road W, Grimsby, Ontario L3M 4E7

The Collins Field Guide to the Birds of East Africa

By J. G. Williams and N. Arlott. 1988. Reissue of 1980 edition. Stephen Greene Press (American distributor Penguin, New York). 415 pp., illus.

This guide is a reprint of the 1980 version. There are no changes of any kind, except for a new publisher (the old one was Collins). This is a pity as its republication afforded an opportunity to update a number of areas. There have been many major social and environmental changes in this region of Africa in the last ten years. Such changes must have had profound effects on the wildlife. Even brief comments in a new preface would have given some feel for the current status. For example, the first bird in the book is the Ostrich, and its range is given as including Ethiopia. Is this still true, or can we assume that it has been largely exterminated?

Despite the authors having missed a wonderful opportunity for an update, the book is still worth buying. Produced in standard, pocket-sized, field guide style, it covers over 650 species of bird, in an area from Eritrea in the north to the Zimbabwe-South Africa border in the south, to Zambia-Lake Tanganyika in the west. Most birds are illustrated in a central colour section.

For the birds covered, the plates and the text are quite satisfactory. The descriptions are precise but generally give sufficient information to be useful in identifying a bird. This does fall down in some places though. For example, Blue-winged Goose, an Ethiopian speciality, is covered in a scant nine lines and a picture of the head.

The book's main failing is what it does not do. The plates show few females, although the text is fairly good in this respect. Many migrants (shorebirds, terns, warblers, for example) are not shown or covered by text. Generally they are listed under a similar (?) species. Twenty-one shorebirds are listed under allied species to the African Snipe-a look-alike ato the common snipe! However all these shorebirds can be found well covered in any single, good European guide. The same is not true for the warblers as some are Asian rather than European and would require more than one book. Other guides on Africa do a much better job in this respect. For example, Newman's *Birds of Southern Africa* gives much better coverage of females, shorebirds, warblers, orioles and others. Serle et al. *A Field Guide to Birds of West Africa* also gives adequate information on these birds but is less instructive than Newman. *Birds of the Middle East and North Africa* is less profusely illustrated and reflects the different ecology north of the Sahara.

A more significant problem is that this system is used on resident birds also. There are seven species of oriole in the region (including one migrant: the European Golden Oriole). They are covered under two species headings, with five being covered as allied species and having limited descriptions. I would find it very difficult to separate the males in the field with this book alone. I think it is impossible to identify juveniles and females. This problem occurs throughout the book. Raptors, owls, rollers, honeycatchers, flycatchers, and finches are all treated this way.

There is little information on abundance. Even crude indications like abundant, common, erratic, and so on would be a useful indication to the visitor. Only when the bird is rare (Short-toed Eagle) or extremely abundant (Red-billed Quelea) are we given any information.

So although I can suggest a visitor buy this book, I would caution that a number of other guides are necessary for successful field identification.

ROY JOHN

8 Aurora Crescent, Nepean, Ontario K2G 0Z7

BOTANY

Vascular Plants of Northern Utah — An Identification Manual

By Richard J. Shaw. 1989. Utah State University Press, Logan. vii + 412 pp. illus. U.S.$27.95.

Students and naturalists in the nine northern counties of Utah and adjacent areas are indeed fortunate. Now, in addition to *A Utah Flora* (Welsh et al. 1987) which contains very detailed descriptions of over 3000 species and *Atlas of the Vascular Plants of Utah* (Albee et al. 1988) which contains distribution maps of some 2438 species plus notes on a large number of rare species in the state, they have a small volume that deals with a very retricted area, is easy to read, and is suitable to carrying in the field.

In *Vascular Plants of Northern Utah* the families and genera are arranged alphabetically within the divisions and classes of ferns, fern allies, pines, dicots, and monocots. The keys to genera and species have been adapted from *Manual of the*

Vascular Plants of Wyoming (Dorn 1977), and have been made as simple as possible. A glossary has been contributed by Lynn R. Firestone. An effort has been made to include the rare plants of the region. A unique feature is the inclusion of commonly cultivated plants, both greenhouse and garden. Family and generic descriptions are short. There are no species descriptions, but following each generic key there is a list of species in which authorities, common names (when available), habitat information, and flowering times are provided. Scattered throughout the book are a selection of line drawings, and particularly useful are those that accompany the glossary.

WILLIAM J. CODY

Biosystematics Research Centre, Central Experimental Farm, Agriculture Canada, Ottawa, Ontario K1A 0C6

The Vascular Plants of British Columbia Part 1 — Gymnosperms and Dicotyledons (Aceraceae through Curcurbitaceae)

By George W. Douglas, Gerald B. Straley, and Del Meidinger. 1989. British Columbia Ministry of Forests, Special Report Series No. 1. Crown Publications, Victoria. 208 pp. $22.00.

For many years J. K. Henry's *Flora of Southern British Columbia and Vancouver Island* (1915) was the bible for students, naturalists, and botanists interested in the vascular plants of British Columbia. This volume is, however, sadly out-of-date and there has been a great need for a complete flora which will encompass the great knowledge which is now available, covering all of the province of British Columbia. For some families of plants such as the sedges, ferns and fern allies, and heathers, the British Columbia Provincial Museum Handbook series have been most useful. For other groups, it has been necessary to rely on floras of adjacent regions such as Hitchcock et al. (1955-1969) *Vascular Plants of the Pacific Northwest* and Hultén (1968) *Flora of Alaska and Neighboring Territories*. More recently, Taylor and MacBryde (1977) produced *Vascular Plants of British Columbia — a Descriptive Resource Inventory*, but this is a rather difficult to use computer print-out, annotated checklist.

The present publication is comprised mainly of dichotomous keys to the genera and species of the Gymnosperm families and the Dicotyledon families Aceraceae to Curcurbitaceae, followed in each genus by a short paragraph for each species in which occasional synonomy, common names, habitat, vegetation zones, and geographic range are given. Budget restrictions have resulted in the elimination of descriptions, illustrations, and distribution maps. This is most unfortunate, and will force the user to turn to one or other of earlier works to get a clear picture of the plant he or she is trying to identify. The alphabetical treatment of the families may pose a problem for some because of the use of more modern family names such as Asteraceae for Compositae and Brassicaceae for Cruciferae without a cross-reference.

Those wishing further information will find the breakdown of the reference into "General" and by family, most welcome. An appendix of excluded species is included. This is most helpful in tying down earlier published records for which no substantiating specimens could be found, but one wonders if it would not have been better to include the garden escapes in the keys, even if they are short-lived or the foreign invaders which have not been observed for many years, because they might readily turn up again.

This is a welcome publication and we will look forward to the three remaining parts which hopefully will follow quickly. The need for a flora of British Columbia complete with descriptions, illustrations and distribution maps is however, still with us.

WILLIAM J. CODY

Biosystematics Research Centre, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6

ENVIRONMENT

Walking the Wetlands: a Hiker's Guide to Common Plants and Animals of Marshes, Bogs, and Swamps

By Janet Lyons and Sandra Jordan. 1989. Wiley Nature Editions, John Wiley & Sons, New York. 222 pp., illus. U.S.$10.95.

This attractive little book could go a long way towards making more people love and appreciate wetlands. The authors restrict themselves to freshwater marshes, bogs, and swamps of the eastern United States. These habitats are briefly described and their importance as water reservoirs and natural pollution filtration areas are mentioned. One hundred and one plants and animals commonly found in these areas are depicted. Each is beautifully illustrated by Ron Schneider in black-and-white on one page and the facing page (usually) carries the text.

This is not a field guide. Too few species over too vast an area are included, and one could take issue with the authors' choices. But that is not the point. The beauty and strength of this little book lies in its ecological approach. Along with each description comes a discussion of the niche of the organism in question. The authors stress the relationships of each plant or animal to its environment, what it is doing there, the part it plays in maintaining the integrity of its habitat, and its role in the food chain. The soil binding capabilities of several aquatic plants are mentioned. We learn of the different ways plants propagate themselves, how they are pollinated, what eats their leaves, fruits or roots or helps to distribute their seeds. Surprisingly many of these wetland species harbour quite an arsenal of poisons or have other interesting defense mechanisms.

Stories about the origins of some of the common or scientific names are included as well as information on past or present uses that people have made of several of the species covered in this book.

The scope of this book is very broad, covering plants and animals of fresh water wetlands of the entire eastern United States. Range extensions further west are mentioned, but extensions into Canada are ignored. This is very disappointing for Canadian readers because a good many of these species do occur in southeastern Canada. A brief synopsis of important wetlands of the United States is in the appendix as well as a useful glossary and a bibliography.

I wonder why the authors chose only to mention distributions within marshes, bogs, or swamps. Several of the species also occur in other habitats. Also I find that the organization of this book is peculiar and detracts from its usefulness. Within each category, species are arranged alphabetically, resulting in such absurdities as the Spring Peeper separated from the rest of the frogs.

In general, I like this book. It reads well, is reasonably accurate, and is a fine little book to promote the enjoyment of wetlands. These are threatened habitats and one way to ensure their preservation is to advertise their attractions in hiking guides such as this one.

FENJA BRODO

Research Associate, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

A Guide to the Queen Charlotte Islands

By Neil G. Carey. 1989. Alaska Northwest Books, Edmonds, Washington. 95 pp., illus. + map. $12.95.

Guide to the Queen Charlotte Islands

By Mary Morris, et al. 1989. Observer Publishing Company, Tlell, British Columbia. 88 pp., illus. $2.95.

Queen Charlotte Islands Trail Hikes and Beach Walks

By Fern Henderson. 1986. Queen Charlotte Islands Museum, Skidegate. 52 pp. $3.95.

Naturalists who visit the Queen Charlotte Islands (QCI) will wonder what literature to read before they go. These three publications are about access to the islands; all appear in frequent or annual editions.

The glossy covers of the two *Guides* are very similar: an inlet of the Pacific, with spruces on a rocky shore, and mountain slopes behind. Either provides adequate touring directions, but they are very different. Carey is a wandering naval Californian. His beach-combing attitude is epitomised by an account of an artifact that was "brutally heavy, but I did not leave it behind". He glorifies the mining, whaling, and logging communities that have come and gone, often speaks of Canada as a foreign country, seems to

regard the "few" (page 31) "dignified, mellow-voiced Haida" (page 42) "Indians" (page 19) as archaic curiosities rather than a nation wth a more legitimate claim than British Columbia to the human title to these islands.

The sailing, fishing, and beach-combing directions are extensive, and, I presume, excellent, as this is what the Careys have done on the QCI since 1955. Much of the natural history information is wrong: epiphytic *Isothecium* is called "Spanish Moss", Trumpeter Swans are called Whistling Swans, *Gonyaulax dinoflagellates* is used as a biominal for the casual agent of paralytic shellfish poisoning and the perjorative epithet "overmature" is used of oldgrowth forest. The book closes with one-sided account of the establishment of the Gwaii Haanaas/South Moresby National Park Reserve. This guide reflects one QCI human type: wilderness-seekers who use remnant wilderness without reflecting on how such use diminishes its wildness.

Morris, et al., is a multi-authored publication of the *QCI Observer* newspaper, whose dedication to fairness among intensely diverse human communities is exemplified by an erratum notice for a use of "Masset" (the spelling of the non-Haida settlement), for "Massett" (the adjacent Haida community; 14 Sept 1989). This *Guide* is as diverse as Carey's is narrow, illustrated by both photographs and striking ink drawings by many local artists. Their work also appears (among sharp-edged snip-out vignettes and MacIntosh graphics) in the advertisements, where almost all island establishments are represented. Articles by local naturalists stand beside advocacy advertisements by logging companies. There are detailed street maps and directories for all settlements. Other articles discuss climate, fishing, Haida art, boating, parks, festivals, whale watching, logging road travel, and recent history.

Trail Hikes and Beach Walks details 30 routes through the Spruce and Salal thickets, over the muskeg, and along the beaches of the QCI, ranging from a 15 min stroll to the Kumdis River near Port Clements (#12), to the overnight hikes around Naikoon (#8) and Cumshewa Head (#30). There is a sketchy map, list of topographic maps, and brief accounts of access, trail conditions, walking time, interesting flora and fauna, history, and published references for each route. These are not maintained trails, and some may be invisible to people accustomed to more heavily used areas. The accounts are adequate, but the maps could be more detailed in the next edition.

FREDERICK W. SCHUELER

Research Associate, Herpetology Section, Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

MISCELLANEOUS

The Guild Handbook of Biological Illustration

Edited by Elaine R. S. Hodges. Van Nostrand Reinhold (distributed by Gage, Agincourt). xv + 575 p., illus. $85.00.

This book is a masterpiece, written and edited by perfectionists: biological illustrators. It "is designed to be a reference for the scientific illustrator, other artists, and scientists who do their own drawing or hire illustrators". Most artists work in one or two main media and specialize to perfect a limited range of techniques. What may seem to be an impossibly complex technique or a magical effect in someone else's work, is only the natural development of their experiences. In this multi-authored volume, masters of each field and technique share the hard-won tricks of their craft. We all reap an additional benefit in having each step of an exquisite rendering explained; we can better see what the artist has seen when we know how it was done. Here is a wealth of advice for the illustrator, right from how to discuss the project with the scientist who requires the illustration, through to the displaying and shipping of illustrations.

Part 1 includes discussion of materials and tools and the use and effects of lighting. A very few important things were not mentioned: distilled water is better than tap water for ink and watercolours; brand names and pH information are not given for watercolour papers. Part 2 covers rendering techniques, both traditional and modern. I was impressed by the clarity and thoroughness of instruction, and was constantly surprised by clever tricks and better ways of doing things. It is frustrating, however, to find that original size of artwork is rarely given for the illustrations in this book.

Part 3 discusses subject groups. Its chapters cover Plants, Fossils, Reconstructing Extinct Vertebrates, Invertebrates, Fishes, Amphibians and Reptiles, Birds, Mammals, Animals in Their Habitats, Humans and Their Artifacts, and Medical Subjects. Each of the chapters gives an

informative mini-course in its field, so that an illustrator with no previous understanding of a group can approach it with confidence. Information for handling small delicate fossils and minute plant specimens will be useful for other tiny or fragile subjects. The well-written descriptions of the careful steps in planning for dinosaur reconstruction are fascinating. Profound advice in the section on insects: "*Never* break parts off a type specimen". The Amphibians and Reptiles chapter is obviously based on experience with photographs and preserved specimens rather than working from living animals.The Birds chapter gives a very good general discussion of colour as perceived in a natural setting. The Mammals chapter could have given some tips on the drawing and painting of fur and hair, and advice on eyes, ears and noses, but didn't. Animals In Their Habitats offers sound advice about the use of photographic reference material, and a fascinating discussion of underwater sketching and painting.

Part 4 explains microscopes, graphics for information presentation, map making, photography of works, and reproduction techniques. Part 5 is devoted to business concerns, with advice for freelance illustrators and information about contracts and copyright. The Copyright chapter and the section on taxes deal only with United States law, with no mention of other countries.

Much can be learned by merely studying the tremendous variety of works presented all though the text. The colour plates are exquisite, and the book is of coffee table quality for non-professional nature art watchers. The effect of this book on every reader will be an enhancement of our reverence for the shapes, structure, colours and details of all natural things.

ALETA KARSTAD

Bishops Mills, RR #2 Oxford Station, Ontario K0G 1T0

NEW TITLES

Zoology

†**Advances in the study of *Peromyscus* (Rodentia).** 1989. Edited by Gordon L. Kirkland, Jr. and James N. Layne. Texas Tech University Press, Lubbock. 367 pp., illus. Cloth U.S.$35; paper U.S.$22.

Analysis of wildlife radio-tracking data. 1990. Edited by Gary C. White and Robert A. Garrot. Academic Press, San Diego. c372 pp. U.S.$59.95.

A birder's list of birds of the world. 1990. By Ernest P. Edwards. E. P. Edwards, Sweet Briar, Virginia. c90 pp + maps. U.S.$5.50 plus U.S.$2 handling.

Australian reptiles and frogs. 1990. By Raymond T. Hoser, Pierson (distributed by International Specialized Book Services, Portland, Oregon). 238 pp., illus. U.S.$49.95.

†**Birds of the Canadian Rockies.** 1990. By George W. Scotter, Tom J. Ulrich, and Edgar T. Jones. Western Producer Prairie Books, Saskatchewan. xvi + 170 pp., illus. $22.95.

†**The Chironomidae of the holarctic region: keys and diagnosis, part 3, adult males.** 1989. Edited by Torgny Wiederholm. Entomologica Scandinavica Supplement No. 34. Scandinavian Entomology, Sandby, Sweden. 532 pp., illus. U.S. $97 plus U.S.$5 handling plus U.S.$6 check charge.

†**The ecology of bird communities, volume 1: foundations and patterns; volume 2: processes and variations.** 1990. By John A. Wiens. Cambridge University Press, New York. xiv + 539 pp., illus. and xii + 316 pp., illus. U.S.$65.50 and U.S.$80.

Elephant life: fifteen years of high population density. 1990. By Irven O. Buss. Iowa State University Press, Ames. 296 pp., illus. cU.S.$49.95.

*†**Field guide to western birds.** 1990. By Roger Tory Peterson. 3rd edition. Canadian distributor Thomas Allen, Markham, Ontario. 432 pp., illus. Cloth $29.95; paper $19.95.

†**Frozen fauna of the mammoth steppe: the story of Blue Babe.** 1989. By R. Dale Guthrie. University of Chicago Press, Chicago. xiv + 323 pp., illus. Cloth U.S.$40; paper U.S.$16.95.

Handbook of marine mammal medicine. 1990. Edited by Leslie A. Dierauf. CRC Press, Boca Raton, Florida. c752 pp, illus. cU.S.$176.

†**A list of the fishes of Canada.** 1990. By Don E. McAllister. Syllogeus 64. National Museum of Natural Sciences, Ottawa. 310 pp., illus.

†**Mammals of Oklahoma.** 1990. By William Caire, Jack D. Tyler, Bryon P. Glass, and Michael A. Mares. University of Oklahoma Press, Norman. xiii + 567 pp., illus. U.S.$29.95.

†**The natural history of seals.** 1990. By W. Nigel Bonner. Facts on File, New York. xvi + 196 pp., illus. U.S.$24.95; $33.95 in Canada.

*__The natural history of weasels and stoats.__ 1990. By Carolyn King. Cornell University Press, Ithaca. xviii + 253 pp., illus. U.S.$26.50.

*__Northwoods wildlife: a watcher's guide to habitats.__ 1989. By Janine M. Benyus. Key Porter Books, Toronto. 345 pp., illus. $19.95.

__Ornithology.__ 1989. By Frank B. Gill. Freeman, New York. xiv + 660 pp., illus. U.S.$49.95.

†__Pandas.__ 1990. By Chris Catton. Facts on File, New York. viii + 152 pp., illus. + plates. U.S.$22.95; $29.95 in Canada.

__Peterson first guide to dinosaurs.__ 1990. By John C. Kricher and Gordon Morrison. Houghton Mifflin, Boston. U.S.$4.95.

__Voyage to the whales.__ 1990. By Hal Whitehead. Chelsea Green (Canadian distributor Milestone, Vancouver). 224 pp., illus. U.S.$22.50.

†__Zoo: the modern ark.__ 1990. By Jake Page. Facts on File, New York. 192 pp., illus. U.S.$35. No Canadian Rights.

Botany

__The biology and utilization of shrubs.__ 1989. Edited by Cyrus M. McKell. Academic Press, San Diego. 656 pp. U.S.$125.

__Ecology of soil seed banks.__ 1989. Edited by Mary A. Leck, V. Thomas Parker, and Robert L. Simpson. Academic Press (Harcourt Brace Jovanovich, San Diego).

*__Forest decline and air pollution: a study of spruce (*Picea abies*) on acid soils.__ 1989. Edited by E.-D. Schulze, O. L. Lange, and R. Oren, Springer-Verlag, Berlin, New York. xviii + 475 pp., illus. U.S.$145.

__Identification guide to the trees of Canada.__ 1989. By Jean Lauriault. Translation of 1987 French version. Fitzhenry and Whiteside, Markham, Ontario. 479 pp., illus.

__Perspectives on plant competition.__ 1990. Edited by James B. Grace and David Tilman. Academic Press, San Diego. 484 pp. U.S.$79.95.

__Plant alert.__ 1990. By Deborah A. Metsger. Royal Ontario Museum, Toronto. 26 pp. English + 29 pp. French, illus. $4.95.

Environment

†__The age of the Arctic: hot conflicts and cold realities.__ 1989. Cambridge University Press, New York. xvi + 316 pp., illus. U.S.$59.50.

__Agroecology: part 1, basic ecological concepts in agroecosystems and part 2, agroecosystem design and management.__ 1989. Edited by S. R. Gliessman. Springer-Verlag, New York. xiv + 380 pp., illus. U.S.$89.

__The arctic seas: climatology, oceanography, geology, and biology.__ 1989. Edited by Yvonne Herman. Van Nostrand Reinhold, New York. xii + 888 pp., illus. U.S.$92.95.

__Biological invasions: a global perspective.__ 1989. Edited by J. A. Drake et al. Wiley, New York. xxiv + 525 pp. U.S.$146.

__But not a drop to drink: the lifesaving guide to good water.__ 1989. By Steve Coffel. Rawson (Macmillan), New York. viii + 323 pp. U.S.$19.95.

__Changing landscapes: an ecological perspective.__ 1 990. Edited by I. S. Zonneveld and R. T. T. Forman. Springer-Verlag, New York. xiii + 280 pp., illus. U.S.$69.50.

__The coast of British Columbia.__ 1990. By Rosemary Neering. Alaska Northwest (distributed by White Cap Books, North Vancouver). 160 pp., illus. U.S.$34.95.

__Dangerous river.__ 1990. By R. M. Patterson. Chelsea Green (Canadian distributor Milestone, Vancouver). 240 pp., illus. U.S.$12.95.

*__The ecological experiments: purpose, design, and execution.__ 1989. By Nelson G. Hairston, Sr. Cambridge University Press, New York. xiii + 370 pp., illus. Cloth U.S.$52.50; paper U.S.$24.95.

__Environment in key words.__ 1990. By I. Paenson. Pergamon Press, New York. 2 volumes, 972 pp., illus. U.S.$270.

__Flower power: the fascinating interrelationships between insects and plants.__ 1990. By Jan Taylor. Kangaroo Press (distributed by International Specialized Series, Portland, Oregon). 80 pp., illus. U.S.$29.95.

__Hydrology and management of watersheds.__ 1990. By Kenneth N. Brooks, Peter F. Folliott, Hans M. Gregersen, and John L. Thames. Iowa State University Press, Ames. 400 pp., illus. cU.S.$49.95.

__Integration of environmental education into general university teaching in Europe.__ 1989. Edited by Charles Susanne, Luc Hens, and Dimitri Devuyst.Proceedings of a symposium, Brussels, 7-10 June, 1989. Vrije Universiteit Brussel, Brussel. 396 pp. 650 BF; U.S.$19.

__Remote sensing of biosphere functioning.__ 1990. Edited by R. J. Hobbs and H. A. Mooney. Springer-Verlag, New York. 350 pp., illus. U.S.$98.

Shore ecology of the Gulf of Mexico. 1989. Joseph C. Britton and Brian Morton. University of Texas Press, Austin. viii + 387 pp., illus. Cloth U.S.$49.95; paper U.S.$22.50.

†**Sonoran desert summer.** 1990. By John Alcock. University of Arizona Press, Tuscon. x + 187 pp., illus. U.S.$19.95.

***State of the world, 1989: a Worldwatch Institute report on progress toward a sustainable society.** 1989. By Lester R. Brown, et al. Norton, New York. xvi + 256 pp. U.S.$9.95; $12.95 in Canada.

***Sustainable development and a quality environment.** 1989. Edited by Brian Wildes. Proceedings of a workshop June 4, 1988, Smithers, British Columbia. Northern Institute for Conservation Research, Smithers. 66 pp. $10.

Miscellaneous

Charles Darwin in Australia. 1989. By F. W. Nicholas and J. M. Nicholas. Cambridge University Press, New York. xiv + 175 pp., illus. U.S.$39.50.

***Despite the odds: essays on Canadian women and science.** 1990. Edited by Marianne Gosztonyi Ainley. Vehicule Press (distributed by University of Toronto Press, Toronto). 452 pp., illus. $19.95.

†**The survival factor.** 1990. By Mike and Tim Birkhead. Facts on File, New York. 208 pp., illus. U.S.$24.95. No Canadian Rights.

Tasmania: a guide. 1990. By Sally F. Odgers. Kangaroo Press (distributed by International Specialized Book Services, Portland, Oregon). 224 pp., illus. U.S.$12.95.

Evolution in the outback. By Jan Taylor. Kangaroo Press (distributed by International Specialized Book Services, Portland, Oregon). 128 pp., illus. U.S.$24.95.

Books for Young Naturalists

Animal tracks of the Great Lakes states; Animal tracks of Mid-Atlantic states; Animal tracks of New England; and Animal tracks of the Rocky Mountains. 1989. By Chris Stall. Mountaineers, Seattle. Each 112 pp., illus. U.S.$4.95.

Animals in the winter. 1989. By Susanne Riha. Carolrhoda, Minneapolis. 32 pp., illus. U.S.$14.95.

An ant colony. 1989. By Heiderose and Andreas Fischer-Nagel. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$12.95.

Butterflies of eastern North America. 1989. By Paul A. Opler. Roberts Rinehart, Boulder, Colorado. 48 pp., illus. U.S.$4.95.

Cats, bats, and bears: right before your eyes. 1989. By John R. Wiessinger. Enslow, Hillside, New Jersey. 64 pp., illus. U.S.$13.95.

Dragonfly. 1989. By Barrie Watts. Silver Burdett, Englewood Cliffs, New Jersey. 25 pp., illus. U.S.$6.95.

Eagles, hawks, and other birds of prey. 1989. By Lynda DeWitt. Watts, New York. 63 pp., illus. U.S.$10.90.

Fish, frogs, and snakes: right before your eyes. 1989. By John R. Wiessinger. Enslow, Hillside, New Jersey. 64 pp., illus. U.S.$13.95.

†**Introducing mammals to young naturalists.** 1990. By Ipo Hiller. Texas A&M University Press, College Station. 110 pp., illus. Cloth U.S.$21.50; paper U.S.$12.95.

Riddles about baby animals. 1989. By Jacqueline A. Ball and Ann D. Hardy. Silver Burdett, Englewood Cliffs, New Jersey. 32 pp., illus. U.S.$5.95.

Those amazing leeches. 1989. By Cheryl Mays Halton. Dillon, Minneapolis. 120 pp., illus. U.S.$12.95.

Tule elk. 1989. By Caroline Arnold. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$12.95.

*assigned for review
†available for review

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